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A STUDY OF CRITICAL MATERIALS FOR THE U.S. COAST GUARD.(U)

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LEVEL II

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A STUDY OF CRITICAL MATERIALS FOR THE U.S. COAST GUARD

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JUNE 1978

FINAL REPORT

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16. Abstract

The purpose of this study is to assist the Coast Guard in developing a systematic methodology for dealing with critical materials problems which could affect Coast Guard short- and long-range procurements and programs. The study focuses on assessing the nature of critical materials problems as they impact the Coast Guard and on determining what the Coast Guard can do to alleviate such situations and to seize opportunities.

Within this general framework, the four specific study objectives are: (1) to develop a workable approach and methodology for recognizing, evaluating, and dealing with Coast Guard critical materials problems and opportunities; (2) to identify critical materials used by the Coast Guard, the shortages of which could have a significant effect on the Coast Guard's ability to perform its assigned and projected missions; (3) to identify future systems or technologies that are expected to grow out of materials shortages, and would indirectly affect Coast Guard missions and programs; and (4) to present and analyze examples of the types of critical materials problems that could arise, assess the significance of the problems, and identify and evaluate alternatives and opportunities for coping with the problems.

The study recommended establishment of a critical materials system to be integrated into the existing Coast Guard planning process that would include a Materials Information Center, a capability for in-depth analysis, a procedure for decision-making and the implementation of decisions.

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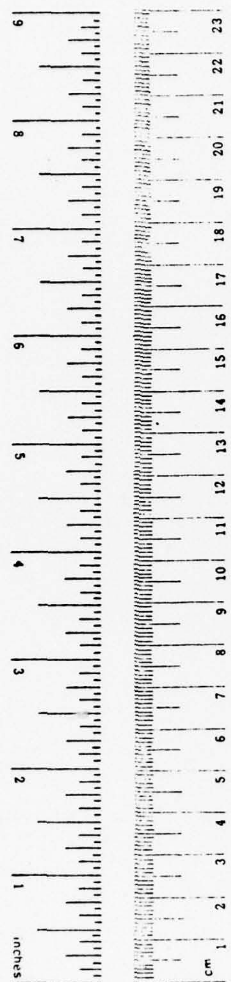
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

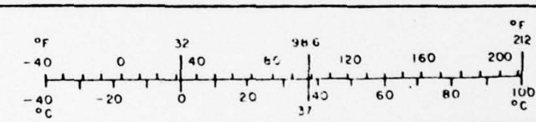
Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



METRIC CONVERSION FACTORS

TABLE OF CONTENTS

TABLE OF CONTENTS
(continued)

SUPPLEMENT TABLE OF CONTENTS

EXECUTIVE SUMMARY

This is the Final Report of work performed by Enviro Control, Inc., on a study of critical materials for the U.S. Coast Guard under Contract DOT-CG-73134-A. The work was performed during the period from October 1977 to June 1978.

A. STUDY PURPOSE AND OBJECTIVES

The purpose of this study is to assist the Coast Guard in developing a plan and a systematic methodology for dealing with critical materials problems which could affect Coast Guard short- and long-range procurements and programs. The study focuses on assessing the nature of critical materials problems as they impact the Coast Guard and on determining what the Coast Guard can do to alleviate such situations and to seize opportunities through planning activities.

Within this general framework, there are four specific study objectives, i.e.:

(1) To develop a workable approach and methodology for recognizing, evaluating, and dealing with Coast Guard critical materials problems and opportunities.

(2) To identify critical materials used by the Coast Guard, the shortages of which could have a significant direct effect on the Coast Guard's ability to perform its assigned and projected missions.

(3) To identify future systems or technologies that are expected to grow out of materials shortages, and would indirectly affect Coast Guard missions and programs.

(4) To present and analyze examples of the types of critical materials problems that could arise, assess the significance of the problems, and identify and evaluate alternatives and opportunities for coping with the problems.

To avoid redundancy and unjustified time and expense, this study does not attempt to add to the large volume of work that has been done so well by both governmental and private groups to determine what materials are or may become critical. It applies the work that has been done by or for other organizations to the Coast Guard's needs, as one input in the analysis to determine whether the Coast Guard should become more concerned about critical materials and, if so, to recommend what the Coast Guard should do.

B. *MAJOR FINDINGS, CONCLUSIONS, AND RECOMMENDATIONS*

- Although temporary shortages of materials used by the Coast Guard have occurred in the past, no shortages were found that have had significant direct impact on Coast Guard operations.

- Unanticipated shortages of necessary materiel can interfere with routine Coast Guard operations, maintenance, and construction programs. These shortages can become severely disruptive to the Coast Guard when they directly impact the logistics chain. They can also result in significant cost increases.

- Critical materials shortages can have indirect impacts on the Coast Guard when they act on the various constituencies that are served by the Coast Guard. This can result in unpredictable and deleterious effects on the Coast Guard's programs unless there is advance planning for accommodating the changes resulting from critical materials shortages.

- The Coast Guard will benefit from a procedural mechanism for identifying, classifying, assessing, and responding to potential critical materials problems and opportunities.

- The Coast Guard should integrate a new critical materials information system into the ongoing Coast Guard planning system that will incorporate the following four basic functional elements (see Figure 1):

    - An information center for monitoring, obtaining, collating, evaluating, and distributing pertinent information from many sources (Critical Materials Information Center).

    - A capability for in-depth analysis and assessment of information to determine whether there is a potential threat or opportunity for Coast Guard activities and missions.

    - A process of decisionmaking to determine what action, if any, should be taken; and what long-range plans should be revised or introduced.

    - The implementation of decisions (including feedbacks to previous phases).

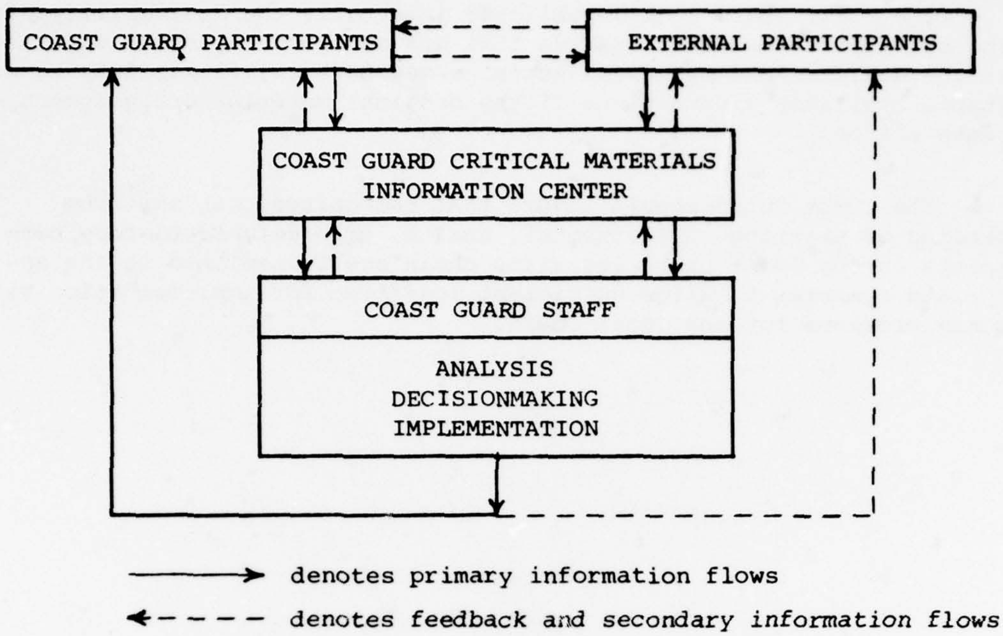


Figure 1

COAST GUARD CRITICAL MATERIALS INFORMATION SYSTEM

- The Coast Guard should expand its interest in critical materials issues and acquaint its personnel with opportunities to extend supply and decrease demand for scarce materials.

- The Coast Guard should obtain early warning of critical materials problems and opportunities by keeping in close contact with the materials establishment in the Government, and with the materials community in general, thus obtaining information as early as possible as to what materials problems are expected. Those who were contacted during this study were most willing to receive our inquiries and appeared to be very receptive to cooperating with the Coast Guard in any steps that it make take to become active in critical materials issues.

- The Coast Guard should pattern elements of future critical materials activities on DOD procedures and should use available information from the DOD system and from other governmental sources for Coast Guard critical materials intelligence gathering.

- The Coast Guard should publicize internally the desirability of using specifications and standards that are as broad as deemed safe, so that the designer and materials engineer may have the flexibility to use suitable available alternatives if the original material or equipment becomes scarce.

- The Coast Guard should insure that recognized problems from impending or existing environmental, health, or safety regulatory constraints on the Coast Guard logistics chain are transmitted to the appropriate agencies to allow sufficient lead time for implementation with minimum problems for the Coast Guard.

Chapter I

INTRODUCTION

A. *STUDY PURPOSE AND OBJECTIVES*

The purpose of this study is to assist the Coast Guard in developing a plan and a systematic methodology for dealing with critical materials problems which could affect Coast Guard short- and long-range procurements and programs. The study focuses on assessing the nature of critical materials problems as they impact the Coast Guard and on determining what the Coast Guard can do to alleviate such situations and to seize opportunities through planning activities.

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(4) To present and analyze examples of the types of critical materials problems that could arise, assess the significance of the problems, and identify and evaluate alternatives and opportunities for coping with the problems.

B. *BACKGROUND*

The Coast Guard, like many other institutions, has become increasingly aware that it could be significantly impacted by future resource shortages. This study is intended to identify and define the nature of potential problems in terms of their possible impact directly and indirectly on Coast Guard programs, planning, procurements, and facility operations; and, in this context, to examine and recommend preventive and control methods.

Critical materials have been a continuous problem for this nation since World War I. It was recognized by the defense establishment in the late 1940's that some form of peacetime planning would be necessary to ensure that strategic resources would be in adequate supply for defense

procurements and for mobilization needs. This feeling was reinforced at the time of the Korean War, during the continuing Cold War, and throughout the Vietnam War. In addition, the Federal Government recognized that there were civilian needs for all of these same materials. Plans and arrangements would be necessary, therefore, to satisfy total national requirements. Over the years, many federal agencies have been involved in this issue, and the President has assigned materials stockpiling responsibilities to the Federal Preparedness Agency of the General Services Administration. Other agencies with materials-related responsibilities include the Department of Commerce, Department of Defense, and Department of the Interior.

In recent years, the critical materials situation and the threat of shortages have been exacerbated and made even more complex by other factors and developments. The energy embargo of 1973-1974, which was imposed as a political weapon by those nations who supplied 20 percent of the total energy that is consumed in the United States, introduced a new dimension to critical shortages. Since it affected everyone in the nation, shortages were brought into our national consciousness, which was hitherto rather lethargic in this respect. Another important factor in recent years was the introduction of environmental control regulations that contributed to reduced growth of productive capacity of both materials and products. There are numerous other economic, technological, and political forces at work nationally and internationally that can produce either temporary or permanent distortions to materials markets and can have impacts on the users of materials as important as a war or a cartel manipulation of prices.

The Coast Guard needs to establish control over the impacts of those materials that are now important, or that can be expected to become important, to the proper fulfillment of the service's mission. It needs a mechanism for identifying, classifying, assessing, and avoiding or responding to potential critical materials problems and opportunities.

C. *SCOPE*

This analysis of Coast Guard critical materials issues includes all materials except pharmaceuticals. Other exclusions are food and energy consumed by Coast Guard personnel and facilities. Food and energy shortages, however, are considered in terms of their indirect impacts on Coast Guard programs.

To avoid useless redundancy and unjustified time and expense, this study does not attempt to add to the large volume of work that has been done so well by both governmental and private groups to determine what materials are or may become critical. It applies the work that has been done by or for other organizations to the Coast Guard's needs, as one

input in the analysis to determine whether the Coast Guard should become more concerned about critical materials and, if so, recommend what the Coast Guard should do.

This analysis focuses on future critical materials issues up to the year 2000. It brackets the three major time frames of Coast Guard planning: the identification of long-range expectations over a 25-year time frame, in the Long-Range View; the midterm plans for the 10-year future as assembled in Program, Facility, and Research and Development Plans; and the shorter term planning and programming as further sharpened in the Plan Summaries, Determinations, Resource Change Proposals, and Budget documents. While all these planning stages must incorporate solutions to the identified problems of critical materials, it is probably the short- and mid-term periods that are the most important to be effectively targeted. The 25-year range would provide the most time for changing directions, but it is the most difficult to project, predict, or even guesstimate. Prudence would prevent Coast Guard decisionmakers from implementing major new thrusts of operational or procurement policy with such a long lead time. There are too many surprises as well as techological innovations that are likely to occur before the year 2000, as an examination of previous long-range forecasts clearly reveals. Nevertheless, it is important to recognize events and impacts that might occur and, to the major degree possible, estimate qualitatively their impacts. This report attempts to do this, readily acknowledging the possibility of significant, unforeseeable events occurring, as already stated. For this reason, periodic review and revision of long-range plans and projections are obviously essential.

Short-range analysis (up to about five years) is useful for consumption impacts but is probably too late to permit effective programmatic shifts. The key period for program impacts is probably 5 to 10 years in the future when the directions of Coast Guard programs are planned, the multiprogram facility needs are identified, research and development projects are initiated, and engineering plans and estimates are assembled.

D. *STUDY APPROACH*

This study has been conducted in a series of steps that involved interviews, literature searches, meetings, briefings, panel discussions, field trips and reports. The general plan has been to:

(1) Collate existing information and experience that could be applied to the Coast Guard situation as preliminarily understood.

(2) Analyze the Coast Guard materials situation in specific detail and develop possible scenarios related to critical materials shortages or major changes, in the national or international supply picture.

(3) Interact and analyze (1) and (2) above in order to define problems, challenges, impacts, and opportunities specific to the Coast Guard.

(4) Develop a methodology to cope with the results of (3).

(5) Test tentative methodology, conclusions, and recommendations through study of selected cases.

A supplemental volume, distributed separately on a limited basis, presents the information developed in the literature search in an annotated format in Appendix A, Annotated Bibliography. Visits, interviews, and contacts with Government and non-Government sources are listed in Appendix B of the same volume.

The interviews within the Coast Guard were keyed to establishing scenarios related to potential shortage problems, identifying organizational responsibilities, analyzing materials usage in the service, and identifying previous Coast Guard responses to national materials shortages. Additionally, they were later used to test preliminary concepts and conclusions. At the same time, these discussions provided the opportunity to communicate to Coast Guard personnel a heightened awareness about national critical materials problems, other agencies' materials information and early warning systems, industrial activities with materials, and possible responses by the maritime industry to critical materials problems.

The meetings with other Federal agency personnel were extremely informative. They provided the entry to the "Federal materials establishment." There are hundreds of Government employees at work all over the country, collecting data, analyzing trends, preparing publications, communicating information, determining policies, establishing an analytical basis for stockpiling decisions, and keeping each other informed about potential future critical materials problems. Those who were contacted were most willing to receive our inquiries and appeared to be very receptive to cooperating with the Coast Guard in any steps that it may take to become active in critical materials issues.

As an illustration, an important step forward in the study was recognition of the opportunity for the Coast Guard to pattern one part of its future system of critical materials activities on Department of Defense (DOD) procedures and to integrate available information from the DOD system and from other governmental sources into the Coast Guard critical materials system. The DOD, through the Office of the Undersecretary of Defense for Research and Engineering (Acquisition Policy) and the Defense Industrial Resources Support Office (DIRSO), uses research, development, engineering, and logistics sources to try to avoid critical materials problems and their impacts on the military services' procurements. Data developed by other sources, such as Department of Commerce (DOC), Department of the Interior (DOI), and General Services Administration (GSA), are also used in the DOD decisionmaking process. As indicated above, DOD welcomed the opportunity for the Coast Guard to participate in its

deliberations, committees, conferences, etc., and was willing to work with the Coast Guard on the latter's problems. Other agencies expressed similar sentiments. Discussions, such as those with DOD, have had a strong impact on the conclusions and recommendations that are given in this study.

As a result of this interaction, a shift in emphasis developed during the course of the study, away from the preparation of definitive lists of potential critical materials and towards the establishment of a Coast Guard decisionmaking system that will be able to anticipate critical materials problems and opportunities in order to implement proactive responses. This concept was tested in discussions with representatives of Coast Guard staff elements G-DSA and G-CPE, who encouraged our efforts towards design of a Coast Guard decisionmaking system.

Having developed a tentative plan for the Coast Guard, the elements of the plan were described at a half-day Critical Materials Workshop, held on 5 January 1978 at Coast Guard Headquarters. In addition to Headquarters and consultant personnel, critical materials experts from DOD, DOI, DOC, GSA, and the Office of Technology Assessment (OTA) were in attendance. The ensuing discussion was most helpful, and the tentative plan was then modified to reflect suggestions and the consensus of opinions. Individual workshop attendees were later contacted to retest the revised proposed system.

Concurrent with the interviews and meetings, other tasks in this study were being performed. These included the establishment of operational definitions of "materials," "critical materials," and other key terminology suitable for Coast Guard needs. Selection of a materials classification system was achieved. After studying a number of systems, the Federal Supply Classification System was chosen as the most appropriate taxonomy of materials for Coast Guard utilization. Preliminary lists of critical materials were compiled. The "List of Materials Critical to the United States" is based on the literature search to find candidates for potentially critical materials at the national level. This list was modified during the interview process to make the necessary transition from national critical materials to specific Coast Guard materials that could become critical. Some materials were added and others dropped to develop the "List of Materials Critical to the Coast Guard." Selection criteria were then developed to identify important critical materials problems and opportunities which could be studied in depth. The criteria were applied to the "List of Materials Critical to the Coast Guard" and items were grouped by numerical rankings of importance.

A number of candidate topics for further analysis were identified. The candidate cases were representative of problems and opportunities which became apparent during the course of the study. The cases that identify potential consumption impacts are caused by a number of factors such as: shortages in raw materials, problems in procurement specifications, limited magnitude of Coast Guard procurement needs, procurement policies, environmental, health, and safety regulatory constraints, and limited domestic production facilities. The cases that identify potential programmatic impacts are derived from increasing worldwide consumption of energy, minerals, food, and freshwater.

Two approaches were taken to develop the list of proposed case studies. The first looked at critical materials that had been identified at the national level and then examined how shortages of these materials could impact the Coast Guard. The second approach was to examine the program structure, facilities, and clientele of the Coast Guard, identify potential scenarios, and then speculate what critical materials shortages could impact the Coast Guard. These are similar approaches to the process used to revise the List of Materials Critical to the United States into the List of Materials Critical to the Coast Guard. For the purpose of presenting candidate case studies, the process was applied again, but more selectively. Summary descriptions of these considerations were presented for each candidate in the Interim Report on 2 February 1978. A list of the candidates is shown in Table I-1.

Table I-1. CANDIDATE CASE STUDIES

	TOPIC
CONSUMPTION IMPACTS	Buoy Chain, 1-1/4" and 1-1/2"
	Electron Tubes
	Submarine Cables
	Icebreaker Propellers
	Batteries
	Halogenated Fluorocarbons
	Paper
	Cordage Fibers
PROGRAMMATIC IMPACTS	Ocean Mining
	Ocean Thermal Energy Conversion
	Photochemical Energy Conversion
	Wave, Tidal, Ocean Current, Salinity Gradient and Hydropower Energy Conversion
	Floating Nuclear Power Plants
	Aquaculture
	Offshore Oil and Gas Exploitation
	Freshwater
	Ferrocement and Prestressed Concrete
	Mineral, Agricultural, and Energy Commodity Movements

A meeting of Coast Guard and contractor personnel was held on 11 February 1978 to select issues for further analysis. Some of the proposed case studies were chosen and others were added by Coast Guard personnel. The agreed list of topics is shown in Table I-2.

Table I-2. SELECTED CASE STUDIES

	TOPIC
CONSUMPTION IMPACTS	Cadmium Mercury Jewel Bearings Icebreaker Propellers Paper
PROGRAMMATIC IMPACTS	Ferrocement and Prestressed Concrete Mineral, Agricultural, and Energy Commodity Movements

These cases were studied in depth and are reported in Chapter IV. Summary descriptions of the unselected candidates are presented in Appendix F.

E. *STRUCTURE OF THE REPORT*

The report is structured to provide the essential information in an easily accessible format. It is presented in two volumes. The first is the body of the report which is suitable for wide distribution inside and outside the Coast Guard. The second supplemental volume containing the Appendices is intended for use by active members of the Coast Guard Critical Materials System.

Chapter I of this volume introduces the study. Chapter II gives a background understanding of critical materials, defines terminology, describes the importance of critical materials to the Coast Guard, provides classification information, and lists the identified critical materials and the criteria for selection. Chapter III develops the proposed methodology for recognizing and solving Coast Guard critical materials problems. Chapter IV contains the analyses of the seven selected topics that were selected to test the methodology. The final Chapter V identifies the key findings, conclusions, and recommendations of the study.

The supplemental volume contains the annotated bibliography, lists of names to contact, the Federal Supply Classification Cataloging Handbook, summaries of other agency information systems, and additional case study summary descriptions.

Chapter II

CRITICAL MATERIALS

A. *THE MATERIALS SYSTEM*

This section will present detailed information about the materials system. It begins with a list of technical terms that are used in the remainder of the report. This is followed with a description of the total materials cycle, an analysis of the causes of critical shortages, and a series of alternatives to reduce demand for the materials.

1. *Key Terminology* [1]

As in all specialized fields and technical areas, there has developed in the field of critical materials a word usage (perhaps even a jargon) with commonly accepted meanings not always in complete consonance with Webster or other dictionary definitions. To ensure mutual understanding, there follow a few selected definitions and explanations of terms as used in this report.

Material(s)—The term "material(s)" has been defined in many ways, most of which are fully equivalent except for minor differences or certain exceptions introduced to apply to the specific topic or problem being examined. For the purposes of this report, the term "material(s)" means natural resources intended to be used for the production of goods, excluding pharmaceuticals. Fuels are also often excluded because of their special nature and the obvious inseparability from the subject of energy; because they have been dealt with so intensively elsewhere, in this study they have not been treated in depth as a Coast Guard consumable—only as they impact other materials considerations and affect Coast Guard program planning.

Materiel—The term "materiel" is generally used as a collective noun to denote collections of materials, equipment or supplies. It is not to be confused with "material," the basic substance from which components of "materiel" are produced.

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[1] These definitions, designed for specific Coast Guard usage, are consistent with but not necessarily identical to those in the following references which are sometimes quoted: *Materials Policy Handbook*, June 1977, prepared for the U.S. Congress Committee on Science and Technology by the Congressional Research Service of the Library of Congress; *Government and the Nation's Resources*, Report of the National Commission on Supplies and Shortages; *Rational Use of Potentially Scarce Metals*, Report of a NATO Science Committee Study Group.

Product(s)—A "product" is something that is created by the processing of materials, generally from the latter's raw or basic form. Thus, it is used to designate materials in various forms such as bars, sheets, and extruded shapes. It may also refer to a piece of equipment or component of equipment, to a tool, or to other items assembled from materials to serve a specific work function.

Life Cycle of Materials—This term describes the flow of materials from their occurrence in or on the earth through various processing stages to utilization and finally to disposal, possibly then reentering an early stage of the cycle.

Critical Materials—"Critical materials" are those materials that are necessary for the operation of a government, agency, industry, nation, etc., and that have the potential of becoming short in supply.

Conservation—As used in this report, "conservation" implies the "frugal use of a scarce and critical material [and] prevention of needless consumption or waste" of it.

Substitution—"Substitution" is the replacement of a critical material or device using it by another material, device, or technique that will serve the same ultimate purpose or function.

Consumption Impact(s)—A "consumption impact" on the Coast Guard from a critical materials shortage is the direct effect on the Coast Guard of the inability to obtain such a material and to consume it in order to permit the Coast Guard to perform its mission. "Consumption impact" is used interchangeably with "direct impact" in this report.

Programmatic Impact(s)—A "programmatic impact" on the Coast Guard from a critical materials shortage is the indirect effect on the Coast Guard resulting from effects on an external constituency served by the Coast Guard. "Programmatic impact" is used interchangeably with "indirect impact" in this report.

Resource(s) and Reserve(s)—A "resource" is a concentration or deposit of naturally occurring material in or on the earth's crust, in such form that economic extraction to produce a useful material is currently or potentially feasible. Resources, therefore, represent total availability under all conditions; however, their quantitative evaluation is very uncertain due to inadequacy of geophysical data, economic projections, and prospecting and mining technology.

A "reserve" is that known resource that can be mined, extracted, or profitably exploited at current prices and with current technology, or that already exists in a developed mine and is available as a feedstock for further processing.

It is useful to examine the relationship between these two terms, or "the dynamics of resources," by studying Figure II-1, developed by Vincent

McKelvey of the U.S. Geological Survey, Department of the Interior. Beginning at the right side of Figure II-1, our knowledge of the location and quantity of ores in the earth's crust is incomplete, and therefore debatable, dependent on our skill in prospecting and discovery. Currently, some emphasis is being placed on improving these skills, to permit a better recognition of what the world's resources really are. Once identified, the resources shift to one of the boxes on the left side of the figure. They may be of such nature and quality that they move directly to the category of reserves as defined above, and thence into production of usable forms. The degree of production, in turn, may be restricted by inadequate productive capacity to meet extant demand, thus creating a shortage even through reserves are adequate. When, due to demand and inadequate reserves, prices rise sufficiently, or when technology improves sufficiently to reduce cost, the subeconomic resources, then being economically exploitable, move into the category of reserves. In the less likely case, with more expansive price increase or technology improvement, the resources in the category of "not currently usable" in the relevant planning period may be able to move to the "subeconomic" level.

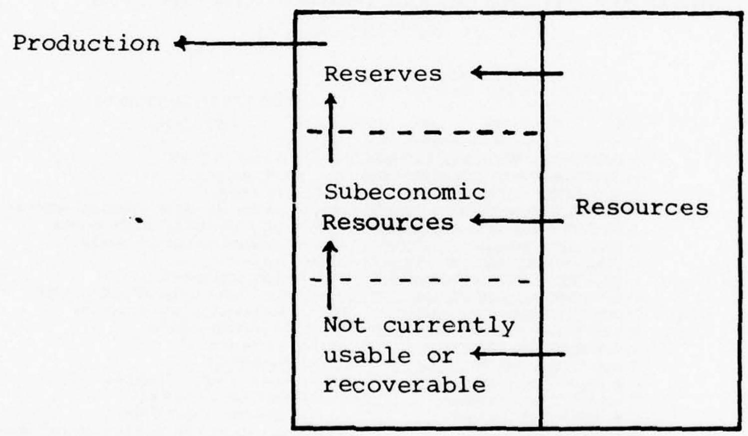


Figure II-1. RESOURCE/RESERVE INTERACTION
(from U.S. Geological Survey)

Renewable Resource(s)--A "renewable resource" is a material that is potentially replaceable by nature, such as wood and agricultural products.

2. The Materials System and Its Significance

It is clear from the definition of materials given above that everything the Coast Guard makes, procures, or uses is involved in the very pervasive field of materials.

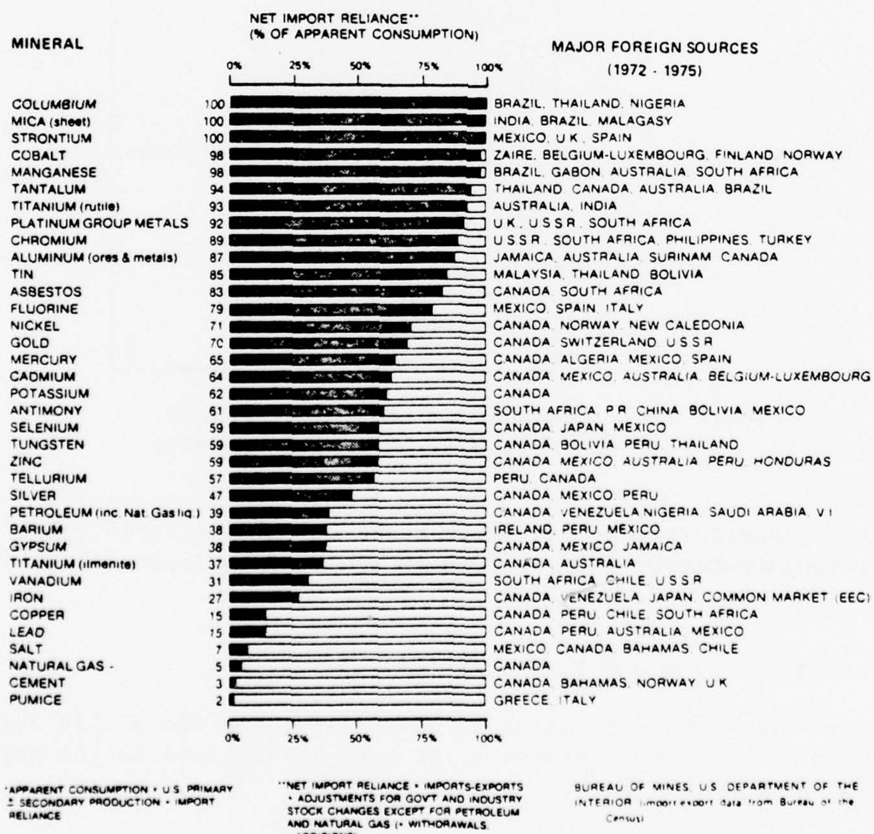
Naturally, the viability of industry and the health of our whole economy depend on the availability, at an acceptable price, of the needed

materials. This has been particularly true in this country since our conversion from an agricultural society to an industrial society, beginning in the 19th century and tremendously intensified in the last five or six decades. During most of this period, there was little concern for the adequacy of materials supply except during wartime, especially World War II. Rapidly advancing technology, abundance of capital, and relatively cheap energy resulted in this century in a fivefold expansion of our economy. At the same time, total materials consumption quadrupled, in spite of increased efficiency in design and production. Energy consumption increased 13-fold. With 5 percent of the world's population, in 1970 the United States consumed 27 percent of the world's materials production, corresponding to over 42,000 pounds per capita per year. From being more an exporter of materials than an importer at the beginning of the century, the United States has become a major importer. Figure II-2 shows the recent (1976) situation; almost two-thirds of the materials are at least 50 percent imported, and a third are over 75 percent imported.

Figure II-2

IMPORTS SUPPLIED SIGNIFICANT PERCENTAGE OF MINERALS AND METALS CONSUMPTION* IN 1976

(Source: Reference [2])



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[2] Bureau of Mines, Office of Mineral Information, *Minerals & Materials/ a monthly survey*, Bureau of Mines, Washington, D.C., May 1977.

The United States has been called the most wasteful country in the world. Indeed, with a few exceptions, it has only been in the past 10 or 20 years that there has been a growing consciousness of the need to carefully examine the balance between demand and supply. The petroleum embargo of 1973 brought home forcefully the precarious position of the United States, not only with respect to petroleum products but also with respect to other materials. Ripple effects from the energy crisis included possible cartels like the Organization of Petroleum Exporting Countries (OPEC) in other areas such as aluminum ores (bauxite) and chrome (the political Rhodesian situation). The shortages of 1973-1974, transient as they were and regardless of their basic causes, certainly exacerbated the concern of industry and the government about materials.

The problem of criticality of materials cannot be dealt with properly without considering at the same time other intimately related factors. It is important to recognize that we are really dealing with a materials system and not an isolated event. This is best described as a materials life cycle, as shown in Figure II-3.

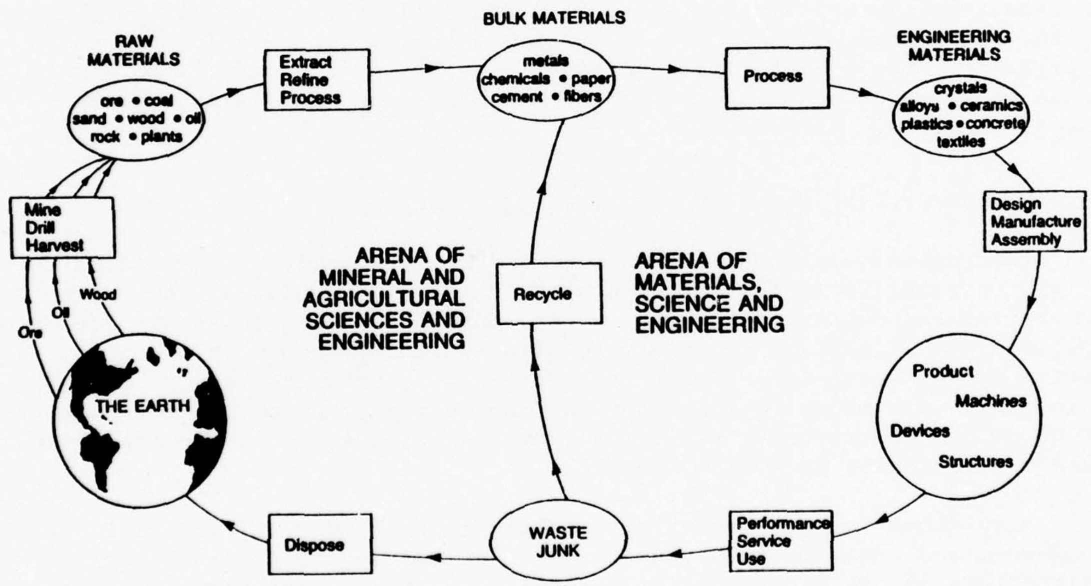

Figure II-3. SCHEMATIC ILLUSTRATION OF THE TOTAL MATERIALS CYCLE
(Source: Reference [3])

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[3] National Academy of Sciences, *Materials and Man's Needs: Materials Science and Engineering,* Summary Report of the Committee on the Survey of Materials Science and Engineering (COSMAT), National Academy of Sciences, Washington, D.C., 1974.

This cycle embraces four major sectors: supply, conversion, use, and disposal—and all phases are interrelated. In the supply sector, the raw materials are drawn from the earth and processed, often using the atmosphere as a source of reactant, into elemental metals, chemicals, or other basic materials. These in turn are converted, in the next cycle phase, through other types of processing, fabrication and manufacturing, into consumer products and goods for use. After the use phase, when the product has served its functional purpose, it enters the last sector of the cycle, namely disposal. This phase has the various options: the product may be recovered for almost direct reentry into an earlier part of the life cycle; it may become nonusable waste returning to the earth; it may go through conversion making it amenable to recycling as a material; or it may be used as a source of energy, a fuel.

It should be noted that every phase and subphase of the materials cycle involve energy and in most cases also involve the environment, usually to the detriment of the latter. Therefore, one cannot divorce a discussion of materials availability from the companion factors of energy and environment. These form a very intimately interacting trichotomy. In fact, the imposition of restrictive regulations for controlling pollution of the environment and for conserving energy has been in some cases the major cause of materials shortages, by introducing conditions which made it impractical or uneconomical to produce the materials or subsequent shapes and components.

3. *The Nature and Causes of Criticality of Supply*

The preceding discussion has sketched the prodigious growth of materials consumption in the United States, both as a beneficial factor in promoting the impressive growth of our economy and as a threat to adequate materials availability necessary to maintain this economy in a healthy state and to serve other essential national requirements such as national security. Two major factors contributing to the problem have been identified as the restrictions resulting from energy shortages (or conservation) and environmental pollution control.

Many other factors affect criticality in the supply of materials, however, and these must be considered in attempting to predict supply situations in the future and in attempting to take precautionary measures to avert disasters or painful disruptions in industry or in the availability of essential goods and products. This discussion will deal with these causes only very briefly, to provide an explanatory background for a later discussion of possible systems for sounding early warnings of shortages to the Coast Guard.

Until quite recently, there has been a high degree of stability (with a few exceptions) and confidence in the supply of materials from foreign sources. Through contractual and trade agreements, U.S. industry has had confident access to mineral sources in foreign countries, total or partial

ownership of these sources, and participation in the processing of the raw materials. The situation has now changed dramatically. The mineral-rich countries, generally in a low state of (and indeed low interest in) industrial development, are becoming industrialized at an increasing rate, with increasing reluctance to lose control of their resources and with a growing demand for redistribution of income internally. The political climate in some countries has changed in a manner less conducive to supplying U.S. needs on the same favorable basis as before. The tremendous global increase in demand for mineral supplies (to which population growth has contributed) has altered the price structures, on the one hand, and, on the other hand, has accelerated the depletion of higher grade ores in some cases. Both of these effects, combined with worldwide inflation, increased cost of energy for processing, and other related price-increase influences, have posed major acquisition problems for the United States. International politics, using mineral supplies as a weapon, have been an additional depressing factor. So it is evident that, aside from the sheer physical availability (or scarcity) of a material resource, a combination of social/political/economic factors has entered the picture. To a marked degree, the physical availability can be quantified or projected. To a very marked degree, the other factors are unpredictable and herein lies one of the major problems in establishing an adequate early-warning system. Added to this difficulty are the components of domestic economic health, domestic inflation, national foreign policy, environmental and energy concerns, cost of capital for building new facilities, tax and investment incentives, and a host of other considerations. It should be noted that shortages may result not only because of an inadequate supply of raw material, but also from inadequate facilities (inadequate either in capacity or cost effectiveness) for processing, and from a "shortage mentality," or fear, that creates artificial—albeit generally transitory—shortages.

There are approaches, of course, for increasing the supply of materials and for increasing confidence in the availability of this supply. These can take the form of stockpiling, technological improvements, expansion of domestic exploration, incentives for exploiting lower grade ores, international political approaches, trade agreements, and general improvement in the world social/political/economic condition. These measures, however, are hardly within the scope or capability of an individual using agency, such as the Coast Guard, to implement.

4. *Reducing the Demand*

Steps to decrease the demand side of the equation can be as important as some of the options for increasing the supply side and commonly do fall within the capability of using agencies. A number of possibilities exist:

(1) The most obvious approach is to replace, in whole or in part, the critical material with one whose supply is assured; i.e., substitution. Where a satisfactory substitute does not exist, an R&D effort may be appropriate. Also, a revision downward in performance requirements for a component to permit use of a somewhat inferior alternative material may be entirely feasible and acceptable.

(2) The product requiring the critical material might be redesigned to eliminate or decrease this material's usage or another type of product be used that would serve the same function (e.g., a transistor for a vacuum tube).

(3) The product could be redesigned for longer life, i.e., greater durability. Some important factors here involve decrease in wear, erosion, corrosion, and deteriorative aging (as in rubber and elastomers).

(4) More efficient recovery of waste products could be effected when they reach the disposal stage (e.g., greater recyclability).

(5) An enhanced conservation sensitivity could be maintained: reduction of scrap, improved manufacturing processes, more definitive specification control, minimized aesthetics, acceptance of a somewhat lower performance level before scrapping the product, more extensive rework and repair.

B. IMPORTANCE OF CRITICAL MATERIALS TO THE COAST GUARD

Just as critical materials problems can beset the nation, so also they may have a crippling impact on the Coast Guard. Shortages of necessary materiel which are not anticipated can interfere with routine Coast Guard operations, maintenance, and construction programs. These shortages can become severely disruptive on the service when they directly impact the logistics chain. They can also result in significant cost increases. They can have other less direct impacts when they act on the various constituencies that are served by the Coast Guard. These indirect effects can have unpredictable and deleterious effects on the Coast Guard's programs unless there is contingency planning for accommodating the changes resulting from critical materials shortages.

It will simplify the discussion to classify impacts of critical materials shortages on the Coast Guard into those that affect consumption and those that affect programs. The term "consumption impact" is used here to identify materials that have internal impact on things or services that the Coast Guard buys and consumes in order to ultimately perform its mission. The term "program impact" is used here to describe impacts on programs in the traditional Coast Guard sense, such as the Search and Rescue (SAR) and Short-Range Aids to Navigation (AtoN) programs. Thus, a critical materials problem with a consumption impact is a problem with a direct effect on an internal process; and a critical materials problem with a program impact has an indirect effect on the service through actions affecting an external constituency served by the Coast Guard.

With respect to consumption or direct impacts, there can be open-market scarcities of raw, semifinished, or finished materials. Since the Coast Guard primarily procures through the Department of Defense and the Federal Supply System, in critical situations there can be competition

among Government agencies with, for example, certain Defense elements having higher priority. Another source of procurement difficulty lies in the commercial products bought on the open market and used both as consumables and nonconsumables for Coast Guard construction programs and at operational facilities. Regardless of the specific shortage route, there can be a direct threat to the service's capacity to fabricate and maintain equipment relatively unique to the Coast Guard, such as buoys, and to Coast Guard needs for continuous shipboard, airborne, and shore operations. Some examples are hardened chrome-steel castings for engine components, tungsten for electrical components and hard surfacing, cadmium for batteries, and buoy chains that have limited domestic sources.

With respect to programmatic or indirect impacts, maritime activities outside of the Coast Guard that are dependent on Coast Guard services may be seriously affected, such as shipping industry, shipyards, offshore minerals industry, and recreational boating. These changes, in turn, affect specific Coast Guard programs. For example, when a material required for the manufacture of a plastic-hulled boat is in short supply and the cost of recreational boats is driven up, the market for boat purchases may shrink and the need for Coast Guard program activities in Recreational Boating Safety (RBS) and SAR may also shrink. An example of an increased program need would occur if waterborne facilities are used more extensively to transport, extract, or process critical materials. Here, the clientele and demand for Coast Guard services are expanding and not shrinking. There could also arise Coast Guard needs for new programs and new technologies. Examples are: new expertise in certifying the safety of vessels which are constructed using substitute materials; inspection and licensing of ships for ocean mining of manganese nodules; and other new regulatory responses in the Commercial Vessel Safety (CVS), Port Safety and Security (PSS), and Marine Environmental Protection (MEP) programs to ensure protection of life, property, and the environment.

In addition to identifying the potential problems of critical materials, it is necessary for the Coast Guard to devise some alternative actions to modify policies and plans in order to accommodate the potential impacts on the Service. These alternatives can be applied at the various decision points in the materials flow system. They must, however, be applied early enough to forestall the effects that could have significant impact. This requires a carefully structured monitoring and analytical system, data base, decision process, and implementation mechanism.

The Coast Guard needs to establish control over the impacts of those materials that are now important or that can be expected to become important to the proper operation of the Service. It needs a method of identifying, classifying, assessing, substituting, and otherwise responding to or avoiding potential critical materials problems.

1. Current Coast Guard Critical Materials Activities

While there have been individuals who were concerned about materials shortages, there has been a relatively low level of awareness of critical materials problems within the Coast Guard. There have been isolated cases where potential problems have been anticipated and then defused through advance procurement or redesign activities. In general, however, there has been no deliberate, systematic collection of readily available materials information from outside of the Service, except on an informal ad hoc basis. There is a large materials establishment within the Government whose members have generally been unaware of Coast Guard programs and facilities that could be impacted by critical materials shortages. These analysts and policymakers in DOD, DOI, DOC, and GSA have had substantial impact in the past in forestalling the unfavorable impacts of anticipated critical materials shortages in their own organizations. They have not been tuned in to Coast Guard materials-related problems.

This study is indicative, of course, of an increasing concern within the Coast Guard for putting itself in a better position to cope with materials shortages, short term and long term.

2. Benefits of Increased Coast Guard Critical Materials Activities

If the Coast Guard were to become more actively engaged in critical materials analysis and then incorporate that data into its policy decision-making, a number of benefits should accrue to itself and indeed to the nation as a whole. A heightened awareness of critical materials problems can produce economic gains through advance planning by stockpiling potentially scarce (and probably more expensive) materials, substituting with more available (and therefore tending to be cheaper) materials, and designing for longer life, increasing definitive specification control, and utilizing materials conservation techniques. More effective and efficient overall utilization of materials would be the net result.

Another benefit from critical materials planning should result from early inputs by the Coast Guard into governmental regulatory proceedings when warranted. Some regulations can be unduly restrictive with respect to materials due to the regulatory agency not being aware of the impact of its proposed regulations on critical government activities. The DOD has been successful in the past in modifying for its purposes regulatory outcomes and, in fact, has gained exemptions through Memoranda of Understanding.

Advance information about materials will be useful in program and facility planning when changes in the Coast Guard's required services to the maritime public will result. Early warning of new technologies, services, construction, and other aspects of the maritime industry that are related to shortages of critical items, such as energy, metals, and potable water, will be very useful for planning future resource needs. A new material technology such as ferrocement vessels might give an

early signal for a new training requirement for Marine Safety personnel. Floating offshore oil and gas extraction facilities and attendant offshore production concerned with energy sources will elicit new responses in the Merchant Marine Safety (MMS), Enforcement of Laws and Treaties (ELT), SAR, AtoN, PSS, and MEP programs. Such advance notice can reduce regulatory lag within the Coast Guard and permit faster responses to the needs of the Service's constituents.

A major benefit of having an ongoing materials system will accrue when the economy heats up and production bottlenecks develop, as in the years 1973-1974. The personnel associated with the established information systems can then be mobilized readily to identify problem areas and to offer alternative solutions to decisionmakers. The economic benefits will be very large during those peak demand periods when shortages can cause excessive waste through hasty substitution or in unused facilities.

Another benefit can devolve from better knowledge of the Coast Guard's activities and capabilities by the other Federal agencies' materials experts. There may be opportunities where a shortage in another agency can be prevented or alleviated by that agency borrowing Coast Guard equipment or material. The reversal of benefit from the Coast Guard to another Government agency would be facilitated by the Coast Guard's entering the materials establishment.

3. Future Coast Guard Critical Materials Activities

The Coast Guard should take an active role in using the existing external materials establishments. There should also be established, within the Coast Guard, an alerting system to identify critical materials problems and opportunities that would or could impact consumption and programs. That system should be able to collect information, analyze it from a Coast Guard point of view, perform evaluations of alternative actions, make the appropriate decisions, and execute the action as required. A general scheme to accomplish these functions is described in Chapter III.

C. USE OF NONSTANDARD AND OVERDESIGNED COMPONENTS

An important distinction should be made between problems arising from scarcity of basic materials (for example, chrome or manganese) and those arising from nonavailability of components. In the latter case, the cause could still be nonavailability of one or more constituent materials, or it could be lack of productive capability or capacity. This section discusses briefly two other important potential contributory causes of component nonavailability, controllable, if at all, within the Coast Guard.

It is a natural aim of design engineers to strive for maximum performance of a component or piece of equipment used to provide a specific function, together with minimum risk of failure or malfunction. Unfortunately, in striving for these goals, the designer often overlooks questions of produceability, availability, repairability, and replaceability—

not to mention unnecessary cost. The result may be an overdesigned component (i.e., a component with unnecessarily high safety factors or restrictive requirements—often referred to as "gold plating") or a component designed exclusively for a given function, having nonstandard features. Either of these results are sometimes unavoidable; however, very often they are unnecessary.

In the case of overdesign, this feature may be minimized by the designer maintaining a continual awareness of this likelihood, by his having a sincere desire to avoid it, and by his having a thorough, analytical understanding and knowledge of performance requirements and functional characteristics. In the case of nonstandard parts, again the designer must maintain awareness and be desirous of avoiding this aspect; but, in addition, he should carefully scrutinize standard or "off-the-shelf" items for adequate performance before designing his own component or adding new features to an existing design. He must be careful to avoid unjustified personal preference and prejudice. Use of nonstandard specifications and parts can lead to availability problems, and almost always to increased cost. The availability problem can affect initial procurement, of course, but may be even more serious when operating units attempt to repair or replace a malfunctioning piece of nonstandard equipment years later.

Several examples are illustrative of a tendency toward nonstandardization. Certain Coast Guard ball valves, utilized within the secondary drainage system, have been specified with special Teflon trim, making them nonstandard. Yet, when such a valve has malfunctioned, it has been replaced satisfactorily with a standard type that is readily available. The use of nonstandard specialty metals has required special welding rods that became difficult to obtain several years ago. A special Walworth valve was specified for a topside washdown system. Investigation revealed that that particular valve had been designed for special conditions in nuclear submarines. Several items, mechanical and electronic in LORAN transmitting equipment, were mentioned in interviews that are produced only by a single or limited source, because of the special requirements imposed. Although no procurement problem has yet arisen in these latter cases, the situation is clearly an imminent one. The shift to solid-state LORAN transmitters will alleviate these threatened shortages but, more importantly, will provide an opportunity for high utilization of standard components.

A corollary to the above—i.e., the desirability of using established material specifications and standard equipment whenever possible—is the desirability of using specifications and standards that are as broad as deemed safe, so that the designer and materials engineer may have the flexibility to use suitable available alternatives if the original material or equipment becomes scarce. In this respect, the use of functional performance requirements in the specification rather than specific and unnecessarily restrictive "how-to" requirements is an important approach to attaining flexibility. This is not always practical, of course, and

must be done cautiously to avoid jeopardizing the needed performance and behavior characteristics. Recognized suitable alternates and flexibility in specifications are particularly important for potentially critical materials and components due to the long lead times required for research, development, or evaluative efforts. The specifications issued by the Department of Defense (DOD), American Society for Testing Materials (ASTM) and Society of Automotive Engineers (SAE) comprise the most comprehensive groups of material and testing specifications prepared and used in this country, and probably in the world.

D. *CLASSIFICATION OF MATERIALS*

A classification system is useful as a systematic base for analyzing material needs, and as a comprehensive means for conveying and obtaining related information. Through this system, the Coast Guard can identify the precise categories of materials in which it is interested. This information can then be conveyed to other Government agencies with the request that the Coast Guard be kept informed about all availability developments related to the selected categories. By the same token, the Coast Guard can concentrate, in perusing the literature, only on material groupings of interest to it. In fact, examination of a relevant homogeneous class of materials may suggest interest about specific substances not previously anticipated. It should be noted, also, that responsibility for Government specification preparation is assigned to agencies by material classes within a system. Beyond that, individuals in Government agencies are often assigned responsibility to keep abreast of developments for specific material classes. Thus the use of a standard classification system provides a very convenient, efficient, systematic, and practical means of communication, as well as means for identifying readily the knowledgeable sources of specific information. The system is also useful for procurement, stocking, and accounting by using standard nomenclature and again permitting information exchange in a simple, convenient form.

1. *Alternative Systems*

There are a number of alternate taxonomies which can be used with direct adoption or with some adaptation. This section describes the most usable choices and selects a recommended system to classify materials for Coast Guard critical materials purposes.

a. *Office of Technology Assessment*

The Office of Technology Assessment (OTA) in a recent study [4] classified materials "in accordance with their intended use." This classification includes the following three categories:

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[4] Office of Technology Assessment, *As Assessment of Information Systems Capabilities Required To Support U.S. Materials Policy Decisions*, U.S. Government Printing Office, Washington, D.C., December 1976.

- *Physical/Structural materials* include all substances in raw, semifinished and finished form used in the manufacture of goods, which remain in identifiable form during a period of use. They include: metallic minerals, metals, construction minerals, wood, paper, cotton, wool, plastics, and ceramics.

- *Reagents and intermediates* include all substances which are used in the manufacture of a finished product but do not remain as part of it. Such substances generally include chemicals, fertilizers, abrasives, solvents, and industrial gases.

- *Energy/Fuels materials* include the various minerals, fuels and products refined from them. They include: petroleum, coal, natural gas, natural gasoline, and liquified petroleum gases.

Some additional categories could be added:

- *Foods* include all edible organic materials which are used for human internal consumption, except pharmaceuticals.

- *Pharmaceuticals* include all drugs, chemicals of medicinal grade, and preparations subject to the Federal Food, Drug and Cosmetic Act or the Public Health Service Act.

This classification system is useful for defining the scope of the critical materials system, but is of limited use as a taxonomy in identifying specific material shortages. For the purpose of this study, all materials except pharmaceuticals will be considered. The internal Coast Guard consumption of food and energy will be excluded, but the indirect effects on the Coast Guard programs from shortages of fuel and energy will be included in this study.

b. National Commission on Materials Policy

The National Commission on Materials Policy was tasked by Section 201 of Title II of Public Law 91-512 with the purpose of "developing a national materials policy." The Commission's report [5] listed materials under Minerals, Forest Products, Paper Materials, Nonfood Agricultural Products, Plastics, and Ceramics. The full listing is shown in Table II-1. This is a useful listing in that it displays the basic materials used in our economy. Its use for the Coast Guard is limited, since it does not permit classification of many forms of materiel such as manufactured products which are used by the Coast Guard and the maritime industries.

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[5] National Commission on Materials Policy, *Material Needs and the Environment Today and Tomorrow*, Final Report, U.S. Government Printing Office, Washington, D.C., June 1973.

Table II-1

CLASSIFICATION SYSTEM OF THE NATIONAL COMMISSION ON MATERIALS POLICY*

MINERALS

Iron and Ferroalloy Ores

Iron	Cobalt
Manganese	Molybdenum
Tungsten	Nickel
Chromium	

Other Metal Ores

Gold	Antimony
Silver	Cadmium
Copper	Magnesium
Lead	Platinum-group metals
Zinc	Selenium
Bauxite	Tellurium
Titanium	Tin
Uranium-radium-vanadium	

Mineral Fuels

Anthracite	Natural gas
Bituminous coal and lignite	Natural gasoline
Crude petroleum	Liquefied petroleum gases

Construction Minerals

Dimension stone:	Sand and gravel:
Limestone	Construction sand
Granite	Gravel
Slate	Glass sand
Marble	Other industrial sand except for abrasives
Basalt	
Sandstone	
Miscellaneous stone	*Fire clay*
Crushed and broken stone:	Magnesite
For cement manufacture	Common clay and shale
For lime manufacture	Gypsum
Other limestone	Native asphalt and bitumens
Granite	Asbestos
Slate	Perlite
Marble	Shell
Basalt	
Sandstone	

Chemical and Fertilizer Minerals

Barite	Bromine
Fluorspar	Calcium and calcium-magnesium chloride
Potash	Magnesium compounds
Borates	Sodium carbonate
Phosphate rock	Sodium sulfate
Sodium chloride	Iodine
Sulfur and pyrites	
Arsenious oxide	

Abrasives and Miscellaneous Minerals

Fuller's earth	Grinding pebbles and tube-mill liners
High-grade clay:	Grindstone, pulpstones, and other special silica stone products
Bentonite	Quartz, ground sand, and sandstone for abrasive purposes
Kaolin	Tripoli and rottenstone
Ball clay	Peat
Miscellaneous high-grade clay	Diatomite
Feldspar	Graphite
Mica sheet	Greensand
Mica scrap	
Pumice and pumicite	
Talc and soapstone	
Emery and garnet	
Vermiculite	

FOREST PRODUCTS

Saw logs	Pulpwood
Veneer logs	Miscellaneous products
Fuel wood	

PAPER MATERIALS

Paper	Paperboard

NONFOOD AGRICULTURAL PRODUCTS

Cotton	Oil crops and others
Wool	Rubber
Fish products	

PLASTICS

Polymers	Synthetic fibers
Elastomers	Other plastic materials

CERAMICS

Construction Ceramics

Glass	Cement
Brick	Tile
Clay products	Mineral wool

Consumer Ceramics

Glass containers	Pressed glass
China	Earthenware
Pottery	Porcelain materials

Industrial Ceramics

Pigments	Oxides
Refractories	Asbestos products
Abrasive products	

Electronic Ceramics

Transistors	Semiconductors
Capacitors	Ferrites and magnets

* *Source:* Reference [5].

c. Bureau of the Census

The Bureau of the Census has developed a series of standard codes to classify business establishments and products manufactured in or imported to the United States. The basic system is presented in the *Standard Industrial Classification Manual* [6]. This SIC system was:

> "...developed for use in the classification of establishments by type of activity in which they are engaged; for purposes of facilitating the collection, tabulation, presentation, and analysis of data relating to establishments; and for promoting uniformity and comparability in the presentation of statistical data collected by various agencies of the United States Government, State agencies, trade associations, and private research organizations." ([6], p.9)

This numerical system is the basis for the codification of products which are produced or sold by the establishments listed in the SIC Manual.

There are two numerical lists of products which contain the materials used by all sectors of the economy, including the Coast Guard. The Census of Manufactures is presented in the form of a *Numerical List of Manufactured Products,* issued in May of 1973 [7]. This list itemizes the 5,500 principal products of the manufacturing industries in the United States. Each production service is assigned a 7-digit code. The product coding structure is an extension of the 4-digit industrial classification in the SIC. The code is designed so that the product coverage is progressively narrowed with the successive addition of digits. This is illustrated with the following:

SIC Code	Level	Description
20	Major group	Food and kindred products
201	Group	Meat products
2011	Industry	Meat packing plants
20111	Product class	Beef, not canned or made into sausage
20111 12	Product	Whole carcass beef, from animals slaughtered at the same plant

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[6] Executive Office of the President, Office of Management and Budget, Statistical Policy Division, *Standard Industrial Classification Manual,* Washington, D.C., 1972.

[7] U.S. Bureau of the Census, Census of Manufactures: 1972, *Numerical List of Manufactured Products (New (1972) SIC Basis)*, Series MC72-1.2, U.S. Government Printing Office, Washington, D.C., 1973.

The Census of Mineral Industries is displayed in the *Numerical List of Mineral Products,* issued in January of 1973 [8]. This is a list of the 180 products or services produced by the mineral industries. It uses a 7-digit coding system identical to that of the Census of Manufactures.

These SIC-based systems of classification may be appropriate to focus Coast Guard attention on relevant materials that might become short in supply and that, therefore, could result in a need for shifts in Coast Guard program activities. However, the system is not closely allied with the numbering systems used to identify the procurement or specifications of items for Coast Guard consumption.

d. Federal Supply Classification System

The Federal Supply Classification (FSC) System has been adapted by the Office of the Secretary of Defense and by the entire Federal Government to classify items of supply. The system is detailed in the Defense Supply Agency's Cataloging Handbook H 2-1, issued in January of 1977 [9].

> "The FSC is a commodity classification designed to serve the functions of supply and is sufficiently comprehensive in scope to permit the classification of all items of personal property. In order to accomplish this, groups and classes have been established for the universe of commodities, with emphasis on the items known to be in the supply systems of the Federal Government.
>
> "The structure of the FSC, as presently established, consists of 77 groups, which are subdivided into 605 classes. Each class covers a relatively homogeneous area of commodities, in respect to their physical or performance characteristics, or in the respect that the items included therein are such as are usually requisitioned or issued together, or constitute a related grouping for supply management purposes.
>
> "The FSC utilizes a four-digit coding structure. The first two digits of the code number identify the group, and the last two digits of the code number identify the classes within each group. Code numbers are so assigned as to make it possible to expand the number of groups and classes as that becomes necessary. In most instances gaps have been left within each group, between the numbers assigned to adjacent classes, to permit the

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[8] U.S. Bureau of the Census, Census of Mineral Industries: 1972, *Numerical List of Mineral Products (New (1972) SIC Basis)*, Series MC72-3.2, U.S. Government Printing Office, Washington, D.C., 1973.

[9] Defense Supply Agency, Defense Logistics Services Center, *Federal Supply Classification, Part 1, Groups and Classes, Cataloging Handbook H 2-1, Department of the Army Supply Bulletin SB 708-21*, Defense Logistics Services Center, Battle Creek, Michigan, January 1977.

insertion of new classes in logical sequence, when necessary, because of technological advances or to accomplish other desirable additions and changes.

"The primary application of the FSC code number is in the National Stock Number (NSN). The NSN for an item of supply consists of the applicable four-digit FSC code number plus the nine-digit National Item Identification Number (NIIN)." ([9], p.iii)

2. Selected System

The Federal Supply Classification (FSC) System is recommended in this study as the most appropriate system for use by the Coast Guard for critical materials purposes. It is the numerical identification basis for the entire Coast Guard logistics system. All Coast Guard as well as all Federal agency procurement items are identified by this system. Even those Coast Guard open-market purchases outside of the Federal procurement system are, or can be, assigned Federal stock numbers through the Coast Guard supply system. In the case of non-Federal purchases that may have programmatic critical materials impacts on the Coast Guard, the scope of materials described in the FSC appears broad enough to include these items. Any material which is purchased by elements of the maritime industry is sure to be included, since the U.S. Navy or Coast Guard will have parallel needs. The only remaining program-related materials are those that are extracted, manufactured, or carried by some constituency of the Coast Guard. Such raw or semiprocessed materials are also included in the FSC. A copy of the Defense Supply Agency Cataloging Handbook H 2-1, of January 1977, is included as Appendix C to this report.

E. SELECTION OF CRITICAL MATERIALS

This section develops a list of materials that could become critical to the Coast Guard. It begins with a listing of materials based on national scope which is then modified to make a list appropriate for Coast Guard use based on certain criteria developed herein. These criteria have been developed both for screening purposes and to indicate the relative significance of critical materials to the Coast Guard. Using these criteria, the various items have been assigned to groups of stated relative criticality.

1. List of Materials Critical to the United States

The List of Materials Critical to the United States in Table II-2 was developed through a search of the available literature, interviews with experts in the materials community, and on examination of national requirements for materials.

*Table II-2. LIST OF MATERIALS CRITICAL TO THE UNITED STATES**

Alumina	Natural gas
Aluminum	Nickel
Antimony	Oils, edible
Asbestos, amosite	Palladium
Asbestos, chrysotile	Petrochemicals
Barium	Petroleum
Bauxite	Phenyl-beta-napthylamine (PBNA)
Beryl ore	Phosphates
Beryllium	Platinum
Bismuth	Potassium
Cadmium	Pyrethrum
Castor oil, sebacic acid	Quartz crystals
Chrome	Rubber, natural
Chromite	Ruby
Coal, low sulfur	Rutile
Cobalt	Sapphire
Columbium	Sebacic acid (see castor oil)
Columbium, carbide powder	Selenium
Columbium, ferro	Silicon carbide, crude
Copper	Silver
Cordage fibers, abaca (manila)	Sperm oil
Cordage fibers, sisal	Strontium
Cotton	Tannin
Diamond, industrial	Tantalum
Down feathers	Tantalum carbide powder
Fertilizer	Tantalum minerals, contained
Fluorine	Tellurium
Fluorspar	Thorium oxide
Gold	Tin
Gypsum	Titanium
Iodine	Tungsten
Ilmenite	Tungsten, ferro
Iridium	Tungsten carbide powder
Iron	Tungsten metal powder
Iron ore	Tungsten ore, contained
Lead	Vanadium
Manganese	Vanadium, ferro
Manganese ore	Vanadium pentoxide
Mercury	Wool
Mica	Zinc
Molybdenum	
Molybdenum, ferro, contained	
Molybdenum disulphide, contained	

**Sources:* Information was obtained from the sources shown on the following page.

SOURCES of information in Table II-2:

Bureau of Mines, U.S. Department of the Interior. *Minerals & Materials/ a monthly survey*. Washington, D.C., May 1977, 58 p.

Comptroller General of the United States. *Report to the Congress: U.S. Actions Needed To Cope With Commodity Shortages*. U.S. General Accounting Office, Washington, D.C., 29 April 1974, 281 p.

Council on International Economic Policy. *Special Report: Critical Imported Materials*. U.S. Government Printing Office, Washington, D.C., December 1974.

General Services Administration, Federal Preparedness Agency. *New Stockpile Goals: The Strategic and Critical Materials Stockpile*, GSA Fact Sheet, 1 October 1976.

General Services Administration, Federal Preparedness Agency. *Stockpile Report to the Congress, July-September 1976*. GSA, Washington, D.C., March 1977, 19 p.

Hood, Edwin M. Shipbuilding Industry Experiences with Material Shortages. Paper presented at DOD Materials Shortages Workshop, January 1975.

Hughes, E. E., et al. *Strategic Resources and National Security: An Initial Assessment*. Report for Defense Advanced Research Project Agency prepared by Stanford Research Institute, ARPA Order No. 2628, August 1974.

National Academy of Sciences, *Materials Technology in the Near-Term Energy Program*. National Academy of Sciences, Washington, D.C., 1974, 121 p.

National Commission on Supplies and Shortages. *The Commodity Shortages of 1973-1974: Case Studies*. U.S. Government Printing Office, Washington, D.C., August 1976.

Naval Surface Weapons Center (M. E. Houser and M. I. Fauth). *Alternate Sources for Propellant Ingredients*, NSWC/WOL/MP 76-19. Naval Surface Weapons Center, 7 July 1976.

NATO Science Committee Study Group. *Rational Use of Potentially Scarce Materials*. NATO Scientific Affairs Division, Brussels, Belgium, 1976.

Office of Minerals Policy Development, U.S. Department of the Interior. *Critical Materials: Commodity Action Analyses: Aluminum, Chromium, Platinum and Palladium*. U.S. Department of the Interior, Washington, D.C., March 1975.

Universal Technology Corporation. *A Survey and Technoeconomic Assessment of Critical and Essential Air Force Metallic Product Forms*, Report #UT-S359-1. Universal Technology Corporation, Dayton, Ohio, 15 October 1974.

Universal Technology Corporation. *A Survey and Technoeconomic Assessment of Critical and Essential Air Force Metallic Product Forms*, Report #UT-S359-1, Part II. Universal Technology Corporation, Dayton, Ohio, 13 January 1975.

The list is selective, to a certain degree, but considered adequate to represent the national situation to the Coast Guard. Except in special cases, generic terms are used throughout the list; although in some cases only a special grade or form of the material may be critical. For example, manganese is listed as a single item although the federal stockpile contains nine different forms of upgraded manganese. Similarly, the national stockpile identifies some materials by their region of origin. The geographical regions are not shown in the generic listing. Products are excluded from the list except for a few common exceptions. Items that are manufactured from the listed materials, though they may be critical, are not listed. For example: jewel bearings are not listed even though they are stockpiled and are considered critical by the Federal Preparedness Agency; however, sapphires and rubies that are used for bearing material are listed. Finally, a few items of low criticality have been omitted, together with pharmaceuticals, the latter in keeping with the definition of materials given above for this report.

2. *List of Materials Critical to the Coast Guard*

The list in Table II-2 was reviewed in the light of the Coast Guard's special requirements. Products not contained in the national list have been introduced on the basis of a series of interviews with Coast Guard personnel and others familiar with the marine industries. A variety of factors that could create criticality have been considered: for example, production facilities in addition to basic material availability. The result is the List of Materials Critical to the Coast Guard shown in Table II-3. Examples of major uses of the materials are also presented, but these are not intended to be definitive or all-inclusive, merely illustrative.

Table II-3. LIST OF MATERIALS CRITICAL TO THE COAST GUARD

MATERIAL	EXAMPLE OF USE
Aluminum/aluminum alloys	Structural applications
Antimony	Hardening lead
Asbestos	Insulation
Beryllium	Copper alloys and bearings
Bismuth	Low-melting alloys and bearings
Cable, submarine	Electrical and communication
Cadmium	Plating and batteries
Chlorofluorocarbon compounds	Propellents, electronic cleaners, refrigerants
Chromium	Stainless steels and high-temperature alloys
Cobalt	Steels and high-temperature alloys
Columbium	Steels and high-temperature alloys
Copper	Electrical wiring and cables
Cordage fibers, abaca and sisal	Lines and fenders
Diamond, industrial	Cutting tools, dies
Down feathers	Cold-weather clothing
Electron tubes	LORAN transmitters
Jewel bearings	Instrumentation
Lead	Batteries
Lithium	Batteries
Manganese	Steels
Mercury	Switches and gyroscopes
Mica	Electrical insulation
Molybdenum	Steels and high-temperature alloys
Natural gas	Heating and propulsion
Nickel	Coating steels and high-temperature alloys
Paper	Forms
Petrochemicals	Plastics
Petroleum	Heating and propulsion
Quartz crystals	Oscillators
Rubber, natural	Aircraft tires and seals
Selenium	Rectifiers
Silver	Alloys
Thorium	Alloys
Tin	Plating and bearings
Titanium	Structural applications
Tungsten	Electrical filaments, steels, high-temperature alloys and hard surfacing
Vanadium	Steels
Water, potable	
Zinc	Plating and cathodic protection

3. *Selection Criteria*

In order to identify potential critical materials problems and opportunities, it is useful to have a screening process that will take in all candidate issues, eliminate trivial cases, and leave the most significant cases to be studied in depth. A set of criteria has been developed that can be applied in a numerical fashion to present a rank order of criticality for all candidate cases. This ranking, therefore, identifies which material shortage threats are most significant and establishes priorities for Coast Guard attention.

The eight criteria are:

- *Import Dependence*—A high degree of Import Dependence would describe a material that is susceptible to interruptions in supply due to changes in import availability. This criterion need not refer to total or almost total dependence on imports. For example, the 30 to 40 percent domestic import dependence for petroleum is high enough to create serious concerns about supply and price.

- *Foreign Vulnerability*—A high potential for Foreign Vulnerability would describe a material that is very susceptible to foreign unilateral acts or multinational economic cartels.

- *Regulatory Sensitivity*—A high degree of Regulatory Sensitivity would describe a material that has high potential to become less available due to its susceptibility to governmental constraints of environmental, safety, or economic regulations.

- *Monopolistic Dependence*—A high degree of Monopolistic Dependence would describe a material that has a very limited number of suppliers and is thus vulnerable to monopoly pricing or production termination.

- *Limited Alternatives*—A high expectation of Limited Alternatives would describe severe difficulties in making rapid shifts to alternative materials or designs. This is a material that cannot be easily designed out of the product that needs it.

- *Technological Necessity*—A high level of Technological Necessity would describe an expectation of few forthcoming technological shifts away from usage of the material. This material will probably remain critical since its usage will not be obviated by expected newer technologies and may, in fact, be increased.

- *Coast Guard Technological Significance*—A high degree of Coast Guard Technological Significance would describe a material that possesses specific inherent qualities or properties that are critical to the functioning of Coast Guard production processes or operational programs. This criterion indicates the importance of the material within the Coast Guard

- *National Technological Insignificance*—A high degree of National Technological Insignificance would describe a material critical to the Coast Guard and not critical to other national industrial processes. This criterion identifies a lack of concern on a national basis about potential shortages of this material, and a need for the Coast Guard to keep its own close watch on availability.

4. *Evaluation with Criteria*

These criteria can be applied to each material listed to be critical to the Coast Guard. A descriptor is used with a numerical index to state the significance of each criterion. They are:

Criticality	*Index*
Maximum	4
High	3
Medium	2
Low	1
Minimum	0

The evaluator assigns the criticality in a sequential manner to ensure that both direct and indirect impacts on the Coast Guard are considered. Each material is considered for each criterion, first for the consumption impacts and then for the programmatic impacts of a shortage on the Coast Guard. Assuming that each of the eight criteria have equal weights, the assigned index numbers are added for each material to yield an aggregate material score. Since the numbers assigned represent qualitative judgments, care must be taken in evaluating the results. The distribution of the scores is assembled, and natural breaks in the data groupings are used to discriminate between three classes of criticality: High, Medium, and Low.

5. *Sample Evaluation*

This process was tested with the List Of Materials Critical to the Coast Guard in Table II-3. Judgments were made for each material for all criteria and the numerical index was added. The numbers were summed and recorded. The result is shown in Table II-4.

Table II-4

APPLICATION OF SELECTION CRITERIA TO MATERIALS CRITICAL TO THE COAST GUARD

MATERIAL	(1) IMPORT DEPENDENCE	(2) FOREIGN VULNERABILITY	(3) REGULATORY SENSITIVITY	(4) MONOPOLISTIC DEPENDENCE	(5) LIMITED ALTERNATIVES	(6) TECHNOLOGICAL NECESSITY	(7) COAST GUARD TECHNOLOGICAL SIGNIFICANCE	(8) NATIONAL TECHNOLOGICAL INSIGNIFICANCE	TOTAL
Aluminum	High 3	Med. 2	Low 1	Med. 2	High 3	Max. 4	High 3	Min. 0	18
Antimony	Med. 2	High 3	Med. 2	Low 1	Med. 2	High 3	High 3	Low 1	17
Asbestos	High 3	Med. 2	Max. 4	Low 1	Med. 2	High 3	Med. 2	Med. 2	19
Beryllium	Max. 4	High 3	High 3	High 3	Med. 2	High 3	High 3	Med. 2	23
Bismuth	High 3	Med. 2	Low 1	Low 1	Med. 2	High 3	High 3	Med. 2	17
Cable, submarine	Min. 0	Min. 0	Low 1	Max. 4	High 3	High 3	Max. 4	High 3	18
Cadmium	Med. 2	Med. 2	Max. 4	Low 1	Low 1	Low 1	High 3	Low 1	15
Chlorofluorocarbon compounds	Low 1	Low 1	Max. 4	Low 1	Med. 2	Low 1	Low 1	Med. 2	13
Chromium	High 3	High 3	High 3	Low 1	High 3	Low 1	High 3	Low 1	18
Cobalt	Max. 4	High 3	Med. 2	Low 1	High 3	Low 1	High 3	Low 1	18
Columbium	Max. 4	High 3	Low 1	Low 1	Med. 2	Med. 2	High 3	Low 1	17
Copper	Low 1	Med. 2	Low 1	Low 1	Low 1	High 3	High 3	Low 1	13
Cordage fibers	Max. 4	Low 1	Low 1	Low 1	Low 1	Low 1	Low 1	Low 1	11
Diamond, industrial	Med. 2	Low 1	Low 1	High 3	High 3	High 3	High 3	Low 1	17
Down feathers	Med. 2	Med. 2	Low 1	Low 1	Low 1	Low 1	Low 1	Low 1	10
Electron tubes	Low 1	Min. 0	Low 1	Max. 4	High 3	Low 1	Max. 4	Max. 4	18
Jewel bearings	High 3	Low 1	Low 1	High 3	Low 1	Med. 2	High 3	Med. 2	16
Lead	Low 1	Med. 2	High 3	Low 1	High 3	Low 1	High 3	Low 1	15
Lithium	Low 1	Low 1	Low 1	Med. 2	High 3	Low 1	Low 1	Med. 2	12
Manganese	Max. 4	Med. 2	Low 1	Low 1	High 3	High 3	High 3	Low 1	18
Mercury	High 3	Med. 2	Max. 4	Low 1	High 3	Low 1	Med. 2	Low 1	17
Mica	Max. 4	High 3	Med. 2	Med. 2	Low 1	Med. 2	Med. 2	Med. 2	18
Molybdenum	Min. 0	Min. 0	Low 1	Low 1	Low 1	High 3	High 3	Low 1	10
Natural gas	Med. 2	Low 1	Med. 2	Low 1	High 3	High 3	High 3	High 3	18
Nickel	High 3	Med. 2	Low 1	Low 1	High 3	High 3	High 3	Low 1	17
Paper	Low 1	Min. 0	Med. 2	Low 1	Max. 4	Max. 4	Med. 2	Med. 2	16
Petrochemicals	Max. 4	Max. 4	Med. 2	Low 1	Max. 4	Max. 4	High 3	Low 1	23
Petroleum	Max. 4	Max. 4	Med. 2	High 3	Max. 4	High 3	High 3	Low 1	24
Quartz crystals	Low 1	Low 1	Low 1	Low 1	Med. 2	Med. 2	Max. 4	Low 1	13
Rubber, natural	High 3	Med. 2	Med. 2	Low 1	Med 2	High 3	Med. 2	Med. 2	17
Selenium	Med. 2	Med. 2	Med. 2	Low 1	Med. 2	Med. 2	High 3	Low 1	15
Silver	Med. 2	Med. 2	Low 1	Low 1	Med. 2	High 3	High 3	Med. 2	16
Thorium	Low 1	Low 1	Med. 2	Low 1	Med. 2	High 3	Med. 2	Med. 2	14
Tin	High 3	Med. 2	Low 1	Low 1	Low 1	High 3	High 3	Low 1	15
Titanium	High 3	Med. 2	Med. 2	Low 1	Med. 2	High 3	Med. 2	Low 1	16
Tungsten	Med. 2	Med. 2	Low 1	Low 1	Med. 2	High 3	High 3	Low 1	15
Vanadium	Low 1	Max. 4	Low 1	Low 1	Med. 2	High 3	High 3	Low 1	16
Water, potable	Min. 0	Min. 0	Low 1	Low 1	Max. 4	Max. 4	High 3	Min. 0	13
Zinc	Med. 2	Med. 2	High 3	Low 1	Med. 2	Med. 2	Med. 2	Med. 2	16

The distribution of the summed scores was examined. Most materials' scores grouped from 15 to 19. This was considered the Middle range. Scores above, from 23 to 24 were considered High; scores below, from 10 to 14 were considered Low. The resultant ranking (with alphabetical order for each range) is shown in Table II-5.

Table II-5

RELATIVE RANKING OF MATERIALS CRITICAL TO THE COAST GUARD

HIGH	Beryllium Petrochemicals Petroleum
MIDDLE	Aluminum/aluminum alloys Antimony Asbestos Bismuth Cable, submarine Cadmium Chromium Cobalt Columbium Diamond, industrial Electron tubes Jewel bearings Lead Manganese Mercury Mica Natural gas Nickel Paper Rubber, natural Selenium Silver Tin Titanium Tungsten Vanadium Zinc
LOW	Chlorofluorocarbon compounds Copper Cordage fibers Down feathers Lithium Molybdenum Quartz crystals Thorium Water, potable

Chapter III

METHODOLOGY FOR RECOGNIZING AND DEALING WITH CRITICAL MATERIALS PROBLEMS AND OPPORTUNITIES

This chapter describes a system that the Coast Guard can institute at little cost, to use existing information systems and ongoing organizational relationships to implement a critical materials control system.

A. *ELEMENTS OF A COAST GUARD CRITICAL MATERIALS SYSTEM*

A process system that would permit the Coast Guard to anticipate and initiate appropriate action on critical materials problems and opportunities with proper lead time and to provide necessary inputs to long-range planning can be considered to consist of four basic functional elements. They are:

(1) A *focal point* or "nerve center" for monitoring, obtaining, collating, evaluating (preliminarily), and distributing pertinent information from many sources.

(2) The specialized, *in-depth analysis and assessment* of this information to determine whether there is a potential threat to,or opportunity for Coast Guard activities and missions.

(3) The process of *decisionmaking* to determine what action, if any, should be taken; and what long-range plans should be revised or introduced.

(4) *Implementation* of decisions and feedback of information to previous phases.

Elements (1) and (2) above are, for the most part, identical in relation to both consumption and programmatic types of impacts; but in elements (3) and (4) the two types require different approaches, considerations, and organizational involvement. These basic elements and their interrelationships are presented graphically in Figure III-1 and discussed in detail in the following sections. It is emphasized that, in general, each element is not self-standing or isolated from the others. There is necessary and beneficial overlap and continuity from one to the other. These elements do not represent organizationally separate units but rather an orderly progression of steps, from ascertaining early warning signs of possible danger up through the decisionmaking process and final implementation of the desired action.

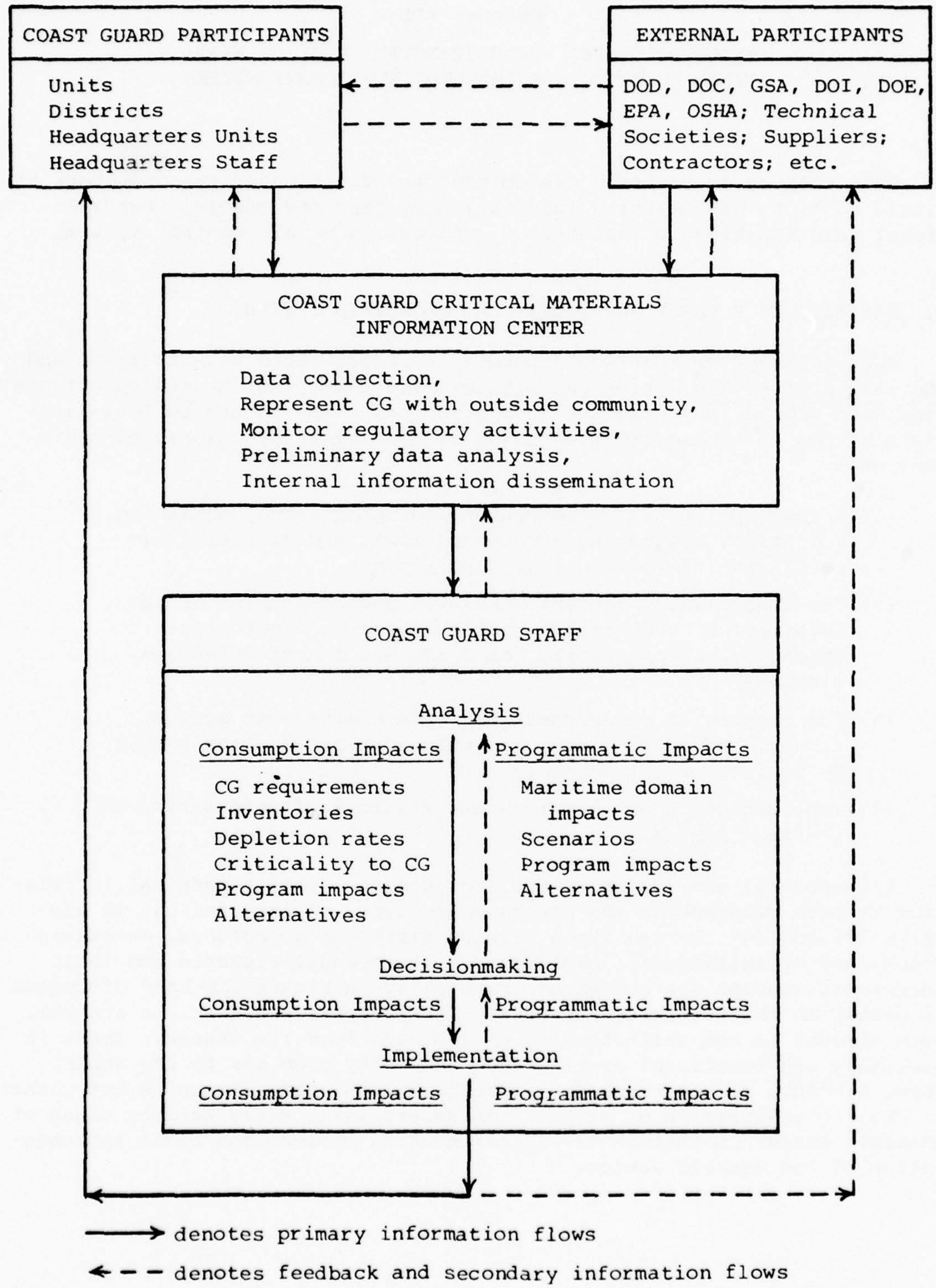

Figure III-1. ELEMENTS, DATA SOURCES, AND INFORMATION FLOWS FOR COAST GUARD CRITICAL MATERIALS SYSTEM

B. *THE CRITICAL MATERIALS INFORMATION CENTER*

The anticipation of critical materials threats and opportunities, their evaluation and assessment, the decisionmaking process, and the subsequent appropriate actions require the availability of an adequate, current data base. This base involves, for the most part, the continuous monitoring of information collected from many sources, preliminary evaluation and assessment of that information in terms of its relevance to the Coast Guard, and dissemination to Coast Guard organizational units that might be affected. There also may be a need to develop the information from a specialized Coast Guard point of view when the material or product usage is unique to the Coast Guard. It follows, therefore, that there should exist within the Coast Guard a recognized focal point with responsibility to perform these functions to satisfy the Coast Guard's needs. A specific organizational element at Headquarters should be designated as the Critical Materials Information Center.

The functions of the *Critical Materials Information Center* should include, as a minimum, the following:

- Collecting, absorbing, and collating pertinent information from many sources. These sources consist of various Government agencies (such as Bureau of Mines (BOM), U.S. Geological Survey (USGS), Occupational Safety and Health Administration (OSHA), Environmental Protection Agency (EPA), Department of Energy (DOE), Department of Commerce (DOC), and Department of Defense (DOD)); attendance at public symposia, seminars, and conferences; the perusal of related publications; and frequent contact and discussion with knowledgeable personnel in the materials field. Additionally, internal Coast Guard sources of data should be processed. Since all organizational sectors and levels of the Coast Guard logistics process have continuous external sources, these can provide excellent pertinent information that impacts on the materials problems. The ability to recognize data that are relevant to the critical materials system is dependent on the "materials awareness" of the receptors. Unless this materials consciousness is developed by key personnel through education and organizational demands, the flow of important data will not be perceived and collected, and therefore not funneled into the central collection point for further collation and processing.
- Imparting Coast Guard needs and concerns to other Government agencies, professional societies, and other non-Government sources such as material producers.
- Participating as active members on interagency committees such as the DOD Materials Availability Steering Committee and participating in public activities such as technical societies.
- Developing a broad directory of information sources and individual experts to turn to for data and guidance when necessary.

- Developing an internal organizational Coast Guard "road map" to permit proper collection and dissemination of information. It is likely that some organizational units themselves must be officially assigned certain cooperative functions, responsibilities, and understandings.
- Maintaining an awareness of activities and proposals in regulatory agencies (such as EPA) and in Congress that could affect availability of Coast Guard materials needs and, where appropriate, initiating action to protect Coast Guard interests.
- Conducting preliminary evaluation and assessment of collected information so as to permit early warning and guidance to appropriate Coast Guard units and staffs, leading to more extensive investigations, decisionmaking, and action where necessary.
- Assisting in the planning of in-depth assessments.
- Disseminating background information within the Coast Guard and, in general, serving as a source of information to the Coast Guard.

Implicit in the preliminary analysis in the Critical Materials Information Center is consideration of the following types of information which have been collected from the above sources:

- Price change trends.
- General demand shifts (with or without price change).
- General supply shifts (with or without price change).
- Stockpile and general inventory status.
- Political events in foreign countries supplying a significant portion of the material and other related international situations.
- Regulatory policies affecting the availability or marketability of the material in question or products made therefrom (e.g., as imposed by EPA and OSHA).
- Technological developments of possible relevance.

It should be emphasized that there are certain functions that the Critical Materials Information Center would not normally be called upon to perform. Particularly, these include the development of national and world data on supply and demand which are done by the Department of the Interior (DOI), DOD, DOC, and GSA; detailed analysis of international and political situations as they affect supply; and similar complex legal, economic, and regulatory analyses that are currently the prime responsibilities of other agencies and are being ably pursued by them. The various information sources already cited, together with others such as the Department of State, thus already provide the basic data, assumptions, and

guidelines for national decisions on stockpiles, tariff negotiations, defense procurements, mineral policies, political activities, and other nationally significant issues related to supply and demand in critical and strategic materials and products. Appendix D describes the information systems of DOD, DOI, DOC, and GSA in some detail. Clearly, the Coast Guard, through the communication channels previously described, can make very efficient use of these sources and derive full benefits from the analyses being conducted by other agencies. Appendix E is a directory of Commodity Specialists at the Department of the Interior's Bureau of Mines, and a directory of Industry Analysts at the Department of Commerce's Office of Business Research and Analysis.

With respect to the Coast Guard personnel to whom the various system responsibilities are assigned, perhaps as supplements to their regular duties, some distinctions must be drawn between those concerned with consumption impacts and those concerned with programmatic impacts. The central responsibility would be given to one or more persons who would have the opportunity and ability to perform the information-gathering functions described above. In the case of the direct impacts of internal consumption of materials, it would be advantageous to designate personnel from those whose primary duties are to research, develop, evaluate, design, modify, repair, replace, procure, stock, transport, or supply various materials for consumption by the Coast Guard. In the case of the indirect, programmatic impact facet of the information system, it would be advantageous to designate personnel from those whose duties require them to make advance plans for the Coast Guard's interaction with various elements of the maritime establishment.

The importance of the Critical Materials Information Center staff being thoroughly familiar with the Coast Guard organization is self-evident. It is particularly significant in terms of what is essentially the final task of the information center; namely, the dissemination of the processed information, formally or informally, to those units and staffs that might be affected by a threatened shortage and thus should be responsible to critically evaluate the assembled information.

C. THE IN-DEPTH ASSESSMENT PROCESS

The critical evaluation of the garnered information in terms of threats or other impacts on Coast Guard needs and operations is a very difficult task and very often is, at best, simply a value judgment. It is for this reason that the data base developed by the Critical Materials Information Center and the special skills, broad experience, and specialized knowledge of the affected Coast Guard units and staffs are so important. Each organizational entity must be thoroughly familiar with its own critical needs and applications, both existing and potential, and be in a position to assess the implication of threatened shortages. The Critical Materials Information Center can provide guidance to the units and staffs for planning their in-depth analyses.

In spite of this strong subjective element of the evaluation process, there are certain specific criteria and semiquantifiable indicators that must be considered. The Critical Materials Information will already have evaluated a number of indicators as they apply to the general (national or global) situation and will have transmitted this data base to the affected unit. To an in-depth review of this preliminary analysis must be added, among others, the following specifics for the direct, consumption type of impact:

- Coast Guard requirements.
- Coast Guard inventories and rates of depletion.
- The criticality of the item to Coast Guard operations.
- The impacts on Coast Guard programs.
- The availability of a substitute material, product, design or function, for both short range and long range.

For the indirect, programmatic type of impact, all the above items must be considered, but obviously the long-range aspects transcend the others. In addition, these factors must be examined in terms of eventual impact on Coast Guard missions, duties, and clients and thus be integrated into potential impacts on Coast Guard programs. For example, the analysis of manganese availability in terms of the direct, consumption impact may show no short-range threat but a long-range general threat of diminishing national availability. Although even this trend may not directly affect the Coast Guard (i.e., it might still get the manganese-bearing steels, bronzes, valves, etc., it needs), the general situation and economic and technological developments could (indeed now appear likely to) lead to mining of manganese nodules on the ocean floor commercially in the next 10 to 20 years. It is this latter situation, rather than direct consumption, that would affect the Coast Guard programs, in terms of Commercial Vessel Safety (CVS), Search and Rescue (SAR), Aids to Navigation (AtoN), Marine Environmental Protection (MEP), etc. It is evident that programmatic impacts are of wider scope than the direct impacts, that they cover a longer time interval much further into the future, and that the effects of the shortages are much more circuitous. The primary Coast Guard participants would be the program planners, the budget analysts, and the policymakers.

The analyses in Chapter IV are presented as examples of the types of assessments that can be made for both consumption and programmatic impacts of potential critical materials. While using a standard format, they show the variations in analytical depth and specificity that can result from the variety of information which is available for each critical material.

In the Evaluation Process, considerable assistance and cooperation may be expected from other Government agencies and industry. Experts in particular problem areas may be solicited for opinions on determining the

probability of criticality and the more likely remedial measures. In more difficult or complex cases, some elaborate tools and techniques may be used, such as the Delphi method, for guidance as to probability of events occurring and their likely results. Continuing experience and a retrospective analysis of historical problems will lead to increasingly effective criteria, methodology, and analyses. The process must be a continuing, educational, and self-evolving one.

D. *THE DECISION PROCESS*

The information monitoring operation and the evaluation process will have established the likelihood of a critical material situation and its short-range and long-range implications for the Coast Guard. The next step is to determine what protective actions should be taken, either to prevent an undesirable event or to ameliorate its effects. To accomplish this, it is necessary to:

(1) Identify alternatives or options for action (including the option of no action).

(2) Evaluate the benefits and costs of each option.

(3) Then, select the optimum course of action, or combination of actions in those cases where the Coast Guard will be significantly affected in a variety of ways.

1. *Identify Alternatives*

In the consumption impact situation, the alternatives will depend upon the particular material and applications in question. There are numerous possibilities to be considered: material substitution; redesign to minimize or eliminate the critical material; substitution of a device, technique, or equipment to perform the same function; operational modification; acceptance of lower performance; technological adjustment; recycling; conservation; stockpiling by the Coast Guard or GSA; and combinations of these. Once the feasible alternatives have been identified, the characteristics required for effective solution of the problem must be specified for each alternative; e.g., quantity, specification, and schedule for stockpiling, or conceptual design of a substitute part.

In the case of programmatic impacts, the situation necessitates a more complex, even imaginative, approach. In essence, a number of possible scenarios must be postulated, and examined or extrapolated in terms of demands on the Coast Guard. Then, possible Coast Guard programmatic responses to satisfy these demands must be explored.

2. *Evaluate Alternatives*

The evaluation of the alternatives can either be an informal judgmental evaluation by one or more Headquarters officials, or it can be a formal cost-effectiveness analysis in cases of considerable difficulty or

importance. In general, all alternatives examined should be designed to solve the problem; hence they should have similar effectiveness. Thus, the cost of the alternative will be the main measure of merit. Both direct and indirect costs to the Coast Guard need to be considered. In some cases, the alternatives will vary in effectiveness; e.g., one alternative might be a more risky or uncertain solution than another. In such cases, the effectiveness as well as cost should be estimated as part of the evaluation procedure.

3. Select the Course of Action

The decision process at Headquarters will entail a joint effort by a number of staff elements and would be expected to flow in a manner similar to that for all multi-Office/Headquarters decisions. The level at which a decision is made depends, of course, on the scope and importance of the situation. For example, a threatened shortage that could be solved by direct procurement planning would generally require a decision only by the functional staff making procurement decisions. On the other hand, if the implications are far-reaching and involve a number of Headquarters Offices, and if agreement among Offices can be reached, then the consensus is presented for approval to the Commandant or to the Chief of Staff in the form of a cleared Commandant's or Headquarters' Intstruction. If agreement is not achieved among Offices, then memoranda, briefings, and discussions with the Commandant and/or Chief of Staff would be required to resolve the issues, with the Commandant or Chief of Staff making the final decision on which option to select.

E. IMPLEMENTATION OF DECISION

The final step in the system is to implement the action previously selected. Here, specific organizational entities must be assigned, either in the staff or field elements, to carry out necessary actions and to adjust for any anticipated changes that will confront the Coast Guard. The effects of these actions should be monitored, reviewed, and used to judge how effective were the prior system functions of data collection, evaluation, decision, and execution. Adjustments to the appropriate parts of the total critical materials system should then be made to improve the entire process. In the case of the programmatic decisions, the time periods involved may be too long to permit early judgment or, terminally, beyond institutional memories to provide enough intelligence to be useful for analysis.

It is important, also, that the system loop be closed by proper feedback to the Information Center, not only from the decision stage but particularly from milestones in the implementation stage. Only in this way will gaps and deficiencies in the basic data phase be corrected and the education and understanding of those who are really the prime movers be enhanced.

Chapter IV

CASE STUDIES

The following case studies are presented as the result of analyses of potential critical materials problems and opportunities. They are divided into studies which illustrate consumption impacts and programmatic impacts. The topics are shown in Chart IV-1.

Chart IV-1. CASE STUDIES

	TOPIC	RATING
CONSUMPTION IMPACTS	Cadmium	Middle
	Mercury	Middle
	Jewel Bearings	Middle
	Icebreaker Propellers	Middle
	Paper	Middle
PROGRAMMATIC IMPACTS	Ferrocement and Prestressed Concrete	Middle
	Mineral, Agricultural, and Energy Commodity Movements	High

The materials selected for case studies generally fell within the middle range of criticality. The exception was due to the high criticality petroleum and petrochemical shortages. They are reflected in Mineral, Agricultural, and Energy Commodity Movements. The topics of Ferrocement and Prestressed Concrete, and Icebreaker Propellers are not listed on Table II-4. They are represented by the elements used as alloying materials in steel and as component materials of nonferrous propellers. All of these were classified as middle criticality.

The purpose of the case studies is to illustrate approaches that can be taken by staff members associated with the Coast Guard Critical Materials System to carry out analyses and assessments. These studies would be carried out to identify in advance how the potential shortages would impact on Coast Guard programs, planning, procurements, and facility operations.

A. *CADMIUM*

Cadmium is a silver-white, soft, malleable metal. It is a relatively rare element used for electroplating, alloying, pigments, batteries, and plastic stabilizers. Cadmium is used for all of these purposes by the Coast Guard. The metal is somewhat vulnerable for domestic availability due to a high level of import dependence and to a high susceptibility to regulatory control by the Environmental Protection Agency (EPA) under the Toxic Substances Control Act.

1. *Sources and Uses*

Cadmium sulfide is the most common form of natural cadmium and is usually mined in association with the zinc sulfide mineral called sphalerite. Although some cadmium minerals are found independently, no ores are mined for their cadmium content alone. The earth's crust is estimated to contain an average of one-half gram of cadmium per ton. Figure IV-1 shows the worldwide distribution of cadmium and zinc [1].

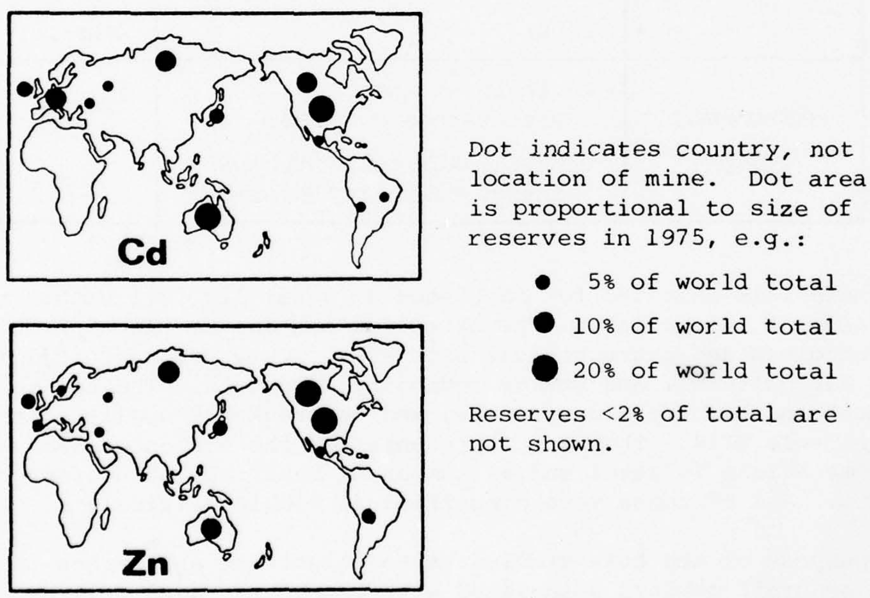

Figure IV-1. LOCATION OF MAIN CADMIUM RESERVES
(Source: Reference [1])

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[1] NATO Science Committee Study Group, *Rational Use of Potentially Scarce Metals*, NATO Scientific Affairs Division, Brussels, Belgium, May 1976.

The United States is presently the world's largest consumer of cadmium, using over 30 percent of the world production as shown by Table IV-1.

Table IV-1

CADMIUM CONSUMPTION BY COUNTRY (average of five years 1969-1973)
(Source: Reference [1])

	%of World Consumption	Self-Sufficiency Index = 1 − (Consumption/Production)[a]
Europe		
Germany	12.2	-1.0
United Kingdom	8.4	-3.9
France	6.5	-0.9
Belgium/Luxembourg	5.6	+0.2
Italy	2.2	+0.1
Other[b]	3.3	
Total	38.2	
North/South America		
United States	33.5	-0.3
Other[b]	0.7	
Total	34.2	
Communist Bloc		
USSR	10.9	+0.3
Czechoslovakia	1.8	-2.5
East Germany	1.5	-2.0
Poland	1.1	+0.5
Other[b]	0.6	
Total	15.9	
Asia		
Japan	10.2	+0.4
Other[b]	0.5	
Total	10.7	
Oceania		
Australia	1.0	+0.7
Other[b]	<0.1	
Total	1.0	
Africa		
Other[b]	<0.1	
Total	<0.1	

[a] If value is + : more than self-sufficient.
If value is - : not self-sufficient.

[b] Countries with less than 1% of world total are combined under 'Other'.

As indicated by the self-sufficiency index in Table IV-1, the United States is not self-sufficient in cadmium. In 1976 the United States imported 64 percent of its cadmium needs [2]. Figure IV-2 traces the cadmium from its sources throughout the world into the United States and to its end uses within the various industries.

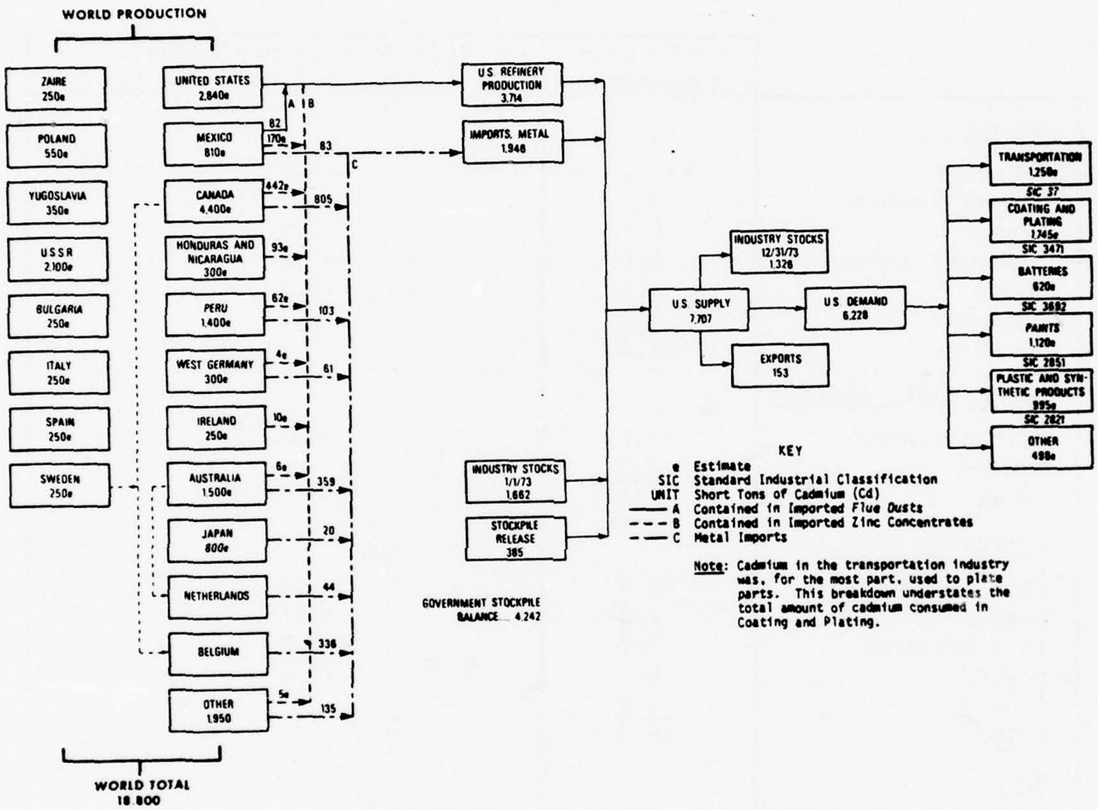

Figure IV-2

CADMIUM SUPPLY-DEMAND RELATIONSHIPS, 1973
(Source: Reference [3])

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[2] Bureau of Mines, *Minerals and Materials/a monthly survey*, U.S. Government Printing Office, Washington, D.C., May 1977.

[3] U.S. Department of the Interior, Bureau of Mines, Cadmium - A Chapter from Mineral Facts and Problems, 1975 Edition, Preprint from Bulletin 667, U.S. Department of the Interior, Washington, D.C., 1975.

Cadmium's importance for certain applications is evidenced by its inclusion in the national stockpile objectives [4]. Stockpiling of cadmium was begun in 1948 and initially completed in 1955. The Agricultural Trade Development and Assistance Act of 1954 allowed the acquisition of cadmium for a supplemental stockpile from 1956 to 1963. During the 1964-1973 period the Federal Government released 4,407 tons, about half the amount previously maintained, for sale. With a goal of 2,223 tons, as of 30 June 1975 there were actually 3,225 tons of cadmium in the national stockpile. The stockpile status as of November 1977 had changed to allow a goal of 12,351 tons with a total inventory of 3,163 tons. Therefore, over 9,000 tons will be added to the stockpile inventory.

The major domestic uses of cadmium and the percentages of total consumption are presented in Table IV-2.

Table IV-2

U.S. UTILIZATION OF CADMIUM
(Source: Reference [5])

Use	% of Total Consumption[a]
Plating	(49.0)
Electronics and communications equipment	12.9
Automotive parts	10.0
Industrial fasteners	9.6
Aircraft and aerospace fasteners	6.2
General industrial hardware	3.8
Ordnance	2.8
General consumer hardware	1.5
Shipboard hardware	1.1
Household appliances	1.1
Nonplating	(51.0)
Heat and light stabilizers for plastics	18.0
Pigments for plastics, paints and printing inks	14.0
Nickel-cadmium batteries	9.0
Alloys and miscellaneous products	10.0

[a]Based on average consumption over the past 10 years.

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[4] National Materials Advisory Board, *A Screening for Potentially Critical Materials for the National Stockpile*, National Academy of Sciences, Washington, D.C., 1977.

[5] National Bureau of Standards, DOC, Memorandum of January 28, 1977, Subject: Request for Abstracts of Papers to be Presented at the Government-Industry Workshop on Alternatives for Cadmium Electroplating in Metal Finishing...

As shown in Table IV-2, electroplating is the largest use of cadmium in the United States. Cadmium has several properties that make it a desirable, and in some cases, the only metal for certain functions. The metal can be deposited at high rates, and with a uniform thickness over intricately shaped objects; allows plated parts to be stamped, due to its ductility; can be soldered, making it advantageous in electrical applications; has superior resistance to alkali and marine environments, even under tropical conditions; has a natural lubricity, advantageous where inspections make repeated assembly and disassembly necessary; and produces no bulky corrosion products. Table IV-3 lists some of the parts typically plated with cadmium.

Table IV-3

TYPICAL PARTS PLATED WITH CADMIUM (Source: Reference [5])

Actuator arms	Magneto parts
Beryllium-copper bushings & bearings	Metal cutters
	Mortar tubes
Bolts	Nails
Brackets	Nuts
Carburetor parts	Old designs
Castings	Piano wire
Catapult hooks	Rifle barrels
Compressor blades	Rivets
Critical high alloy steel	Screws
Dissimilar metal fraying surfaces	Shafts
	Splines
Door panels	Shrouds
Electrical connectors	Stainless steel bushings
Fasteners	Tools
Fittings	Turbine engine blades, vanes & cases
Flanges	
Gears	Washers
Low alloy steel parts heat-treated below 200K psi	Weldments

Cadmium as a metal is also used in nickel-cadmium batteries which perform well in a wide range of temperatures, deliver maximum current with a low voltage drop; and have low operating costs, a long life, and a low self-discharge rate. The batteries find applications as sealed units in portable-rechargeable calculators, tools, appliances, radios, and telephones. As larger, vented cells they are used as aircraft batteries for standby power and light. Table IV-4 shows the distribution of nickel-cadmium batteries in Coast Guard aircraft. The spare inventory maintained for helicopter usage of Ni-Cd batteries is from 30 to 40 units per year. The C-131 is a new acquisition for the Coast Guard, and battery usage levels have not been determined. Any increase in operations caused by the 200-mile economic zone extension will increase battery consumption. At

present, there is only one year's experience, but trends should be established by the end of 1978. Some increase in battery usage has already been noted, but no firm trend has emerged that would require modification of procurement and inventory practices.

Table IV-4

COAST GUARD USE OF Ni-Cd SECONDARY BATTERIES IN AIRCRAFT
(Source: Reference [6])

Aircraft	Battery No./Size	Total Batteries In Use
H-52	1/24-volt	80
H-3F	1/24-volt	38
C-131	2/24-volt	34
C-130	2/24-volt	50[a]
HU-16	1/24-volt	17[a]
VC-4	1/24-volt	1
VC-11	1/24-volt	1
Total		154[a]

[a]The C-130 and HU-16 use lead-acid batteries—not included in total.

The compounds of cadmium also find applications in batteries. Cadmium oxide is utilized in the silver-cadmium oxide battery that is used for satellite and other space applications demanding high discharge rates. The cells are produced on a limited commercial scale, due to their high cost, to provide power for portable tools, television sets, and appliances.

The largest use of cadmium compounds is in the manufacture of pigments. They provide colors in the yellow, orange, and red ranges. Since the compounds offer heat stability up to 600°C, good light and weathering ability, as well as good hiding power and color intensity, they are ideal for use in high-temperature plastic molding. Pigments for plastics, paints, enamels, lacquers, and printing ink are also made from various cadmium compounds.

Vinyl is stabilized during processing and protected as an end product against light degradation by various cadmium compounds. Thermoplastics, like polyvinyl chlorides, are also stabilized by cadmium and barium salts in combination. The plastics using cadmium salts as stabilizers are clear and are used in general packaging.

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[6] Interview with Mr. Dick Hudson, U.S. Coast Guard Aircraft Repair and Support Center, Elizabeth City, North Carolina, 14 March 1978.

Several uses of cadmium fall into the category of alloys and miscellaneous applications. The low melting point of cadmium makes it useful for low-melting alloy items such as fire detection and sprinkler systems. As an alloy with silver, cadmium and cadmium oxide are used for electrical contact applications including motor starting switches, light-duty circuit breakers, and silver brazing alloys. The addition of cadmium to copper for automobile radiators hardens the copper while preserving its mechanical stability and thermal conductivity.

2. *Past Shortage Experience*

No indications of past shortages could be identified during the course of this study [7].

3. *Historical Trends*

The data in Table IV-5 provide cadmium production, components of U.S. supply, and a breakdown of how cadmium is consumed by U.S. industry. Total cadmium demand in the United States has increased 42.8 percent, from 8.67 million pounds in 1964 to 12.34 million pounds in 1974.

Table IV-5

CADMIUM SUPPLY-DEMAND RELATIONSHIPS, 1964-1974

(Source: Reference [3])

(Short tons)

	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
World production:											
United States	2,350	2,200	2,350	1,900	2,100	2,325	1,778	1,777	2,390	2,840	2,066
Rest of world	11,654	10,914	11,972	12,635	14,453	17,067	16,450	15,344	16,110	15,960	16,734
Total	14,004	13,114	14,322	14,535	16,553	19,392	18,228	17,121	18,500	18,800	18,800
Components of U.S. supply:											
Domestic mines	2,350	2,200	2,350	1,900	2,100	2,325	1,778	1,777	2,390	2,840	2,066
Government release	51	---	184	516	404	1,378	3	1	479	385	1,006
Imports, metal	552	1,061	1,679	794	964	539	1,246	1,750	1,211	1,946	1,956
Imports, content of ore and flue dust	2,421	2,556	2,898	2,069	3,028	3,655	2,957	2,188	1,762	874	1,433
Industry stocks, Jan. 1	1,106	1,426	2,042	1,751	1,139	924	1,127	2,391	2,636	1,662	1,326
Total U.S. supply	6,480	7,243	9,153	7,030	7,635	8,821	7,111	8,107	8,478	7,707	7,787
Distribution of U.S. supply:											
Industry stocks, Dec. 31	1,426	2,042	1,751	1,139	924	1,116	2,391	2,657	1,662	1,326	1,569
Exports	720	37	190	346	265	542	187	33	509	153	31
Demand	4,334	5,164	7,212	5,545	6,446	7,163	4,533	5,417	6,307	6,228	6,187
U.S. demand pattern:											
Transportation	475	700	913	850	990	1,100	885	1,058	1,250	1,250	1,100
Coating and plating	1,720	2,001	3,150	2,450	2,925	3,263	1,380	1,650	1,900	1,745	1,900
Batteries	234	308	250	200	200	250	150	180	450	620	600
Paints	1,300	1,280	1,000	555	675	725	648	775	950	1,120	1,100
Plastics and synthetic products	375	425	1,196	1,108	1,261	1,350	1,193	1,425	1,250	995	1,000
Other	230	450	703	382	395	475	277	329	507	498	487
Total U.S. primary demand	4,334	5,164	7,212	5,545	6,446	7,163	4,533	5,417	6,307	6,228	6,187

[7] Interview with Mr. John Lucas, Commodity Analyst, Bureau of Mines, Washington, D.C., 10 March 1978.

Figure IV-3 provides an indication of how the end uses of cadmium have shifted between 1964 and 1973.

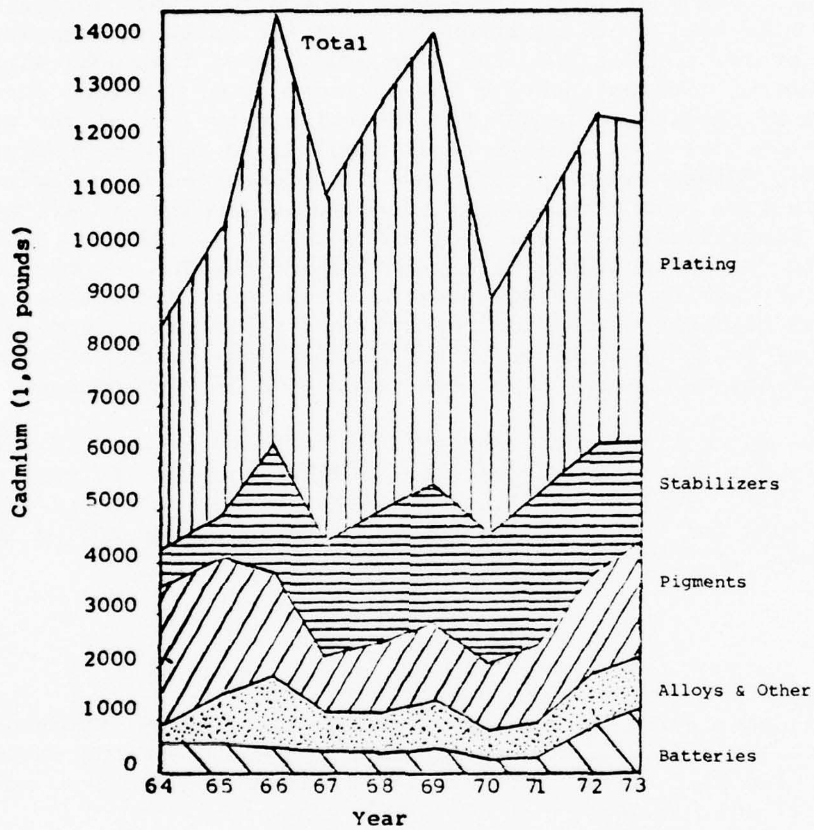

Figure IV-3

CADMIUM CONSUMPTION IN THE UNITED STATES BY END USE 1964-1973
(Source: Reference [8])

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[8] Dyckman, Edward J., Defense Industrial Resources Support Office, OASD(I&L)WP, *Cadmium: Utilization, Environmental Impact, Materials and Process Specifications, and Substitutes*, Department of Defense, Washington, D.C., 26 June 1975.

4. *Factors Affecting Consumption*

In July 1977, cadmium was designated by the EPA as one of the chemicals requiring "serious investigation to determine appropriate regulatory actions to be taken under the Toxic Substances Control Act" [9]. A survey performed in 1973 by the Food and Drug Administration indicated dietary levels of cadmium at 72 to 90 percent of the tolerable intake levels set by the World Health Organization/Food and Agricultural Organization (WHO/FAO). Several regulations have been promulgated that deal with limiting the amount of cadmium entering the environment or limiting personal exposure to cadmium in foodstuffs, drinking water, or at the workplace. The EPA has published interim final regulations for electroplating effluents [10]. Standards of performance and pretreatment to limit cadmium in effluents have been established; these may be applied to all electroplating facilities, both existing and future. In 1977 the National Institute for Occupational Safety and Health (NIOSH) recommended exposure levels for cadmium in the workplace. The Safe Drinking Water Act of 1974 also sets maximums on cadmium content in potable water supplies. This regulatory activity is based on the established toxicity of cadmium. The toxic effects of cadmium have been documented in many sources [11,12].

Price changes in cadmium have little effect on its utilization, due to the fact that cadmium makes up a small portion of the cost of the end product [13]. Table IV-6 illustrates that prices increased 141 percent between 1954 and 1974. During that same period, consumption increased by 67 percent [3].

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[9] U.S. Navy Bureau of Medicine, (BUMED-55-1-GML:bw) Memorandum, Subj: Fifteen (15) chemicals designated by EPA for serious investigation to determine appropriate regulatory action to be taken under TOSCA, of 27 July 1977.

[10] Bureau of Mines, *Mineral Commodity Summaries, 1978: An Up-to-Date Summary of 95 Mineral Commodities*, U.S. Government Printing Office, Washington, D.C., 1978.

[11] Flick, D. F., H. F. Kraybill, and J. M. Dimitroff, Toxic effects of cadmium: a review, *Environmental Research* 4:71-85, 1971.

[12] DHEW, National Institute for Occupational Safety and Health, *Criteria for a Recommended Standard--Occupational Exposure to Cadmium*, U.S. Government Printing Office, Washington, D.C., August 1976.

[13] National Materials Advisory Board, *Trends in Usage of Cadmium*, NMAB-255, National Academy of Sciences, Washington, D.C., November 1969.

Table IV-6

HISTORICAL PRICES FOR CADMIUM

(Source: Reference [3])

Year	Average Annual Price, Dollars per Pound	
	Actual Price	Constant 1973 Dollars
1954	$1.70	$2.93
1955	1.70	2.89
1956	1.70	2.79
1957	1.55	2.45
1958	1.45	2.24
1959	1.30	1.97
1960	1.50	2.24
1961	1.70	2.51
1962	1.75	2.55
1963	2.55	3.67
1964	3.00	4.26
1965	2.58	3.59
1966	2.42	3.28
1967	2.64	3.46
1968	2.65	3.34
1969	3.27	3.94
1970	3.57	4.08
1971	1.92	2.10
1972	2.56	2.70
1973	3.64	3.64
1974	4.09	3.71

5. *Supply and Demand Projections*

Since cadmium is a by-product of the zinc smelting process and not mined directly, cadmium availability is somewhat related to the zinc demand. However, there is some moderation in that cadmium-enriched residues may be stockpiled by the zinc producers. These can work to increase cadmium supplies during slack periods of zinc production or to decrease cadmium supplies during active zinc production.

The Bureau of Mines (BOM) has developed forecasts for global and domestic demands for cadmium to the year 2000. Table IV-7 shows forecast ranges for 1985 and 2000 for the United States and the rest of the world. Table IV-8 shows projections by domestic end uses for the year 2000.

Table IV-7

SUMMARY OF FORECASTS OF U.S. AND REST-OF-WORLD CADMIUM DEMAND, 1973-2000

(Source: Reference [3])

(Short tons)

	1973	2000 Forecast range		Probable		Probable average annual growth rate 1973-2000, (percent)
		Low	High	1985	2000	
United States:						
Total	6,228	9,300	17,200	8,600	12,700	2.7
Cumulative	---	208,500	295,600	89,200	249,500	---
Rest-of-world:						
Total	12,600	21,500	33,600	18,000	28,000	3.0
Cumulative	---	454,200	588,700	184,200	528,300	---
World:						
Total	18,828	30,800	50,800	26,600	40,700	2.9
Cumulative	---	662,700	884,300	273,400	777,800	---

Table IV-8

PROJECTIONS AND FORECASTS FOR U.S. CADMIUM DEMAND BY END USE, 1973-2000

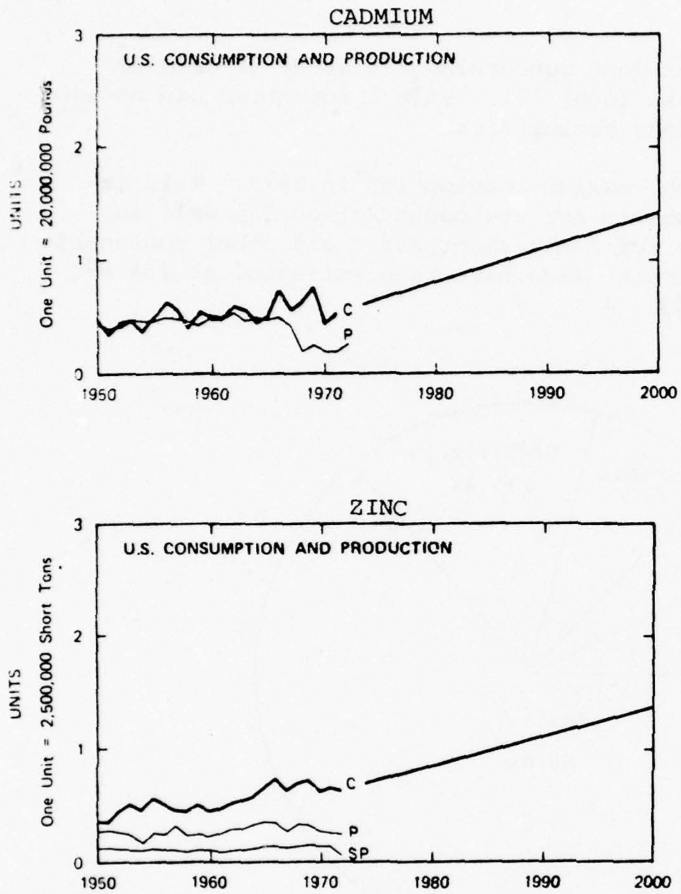
(Source: Reference [3])

(Short tons)

End use	1973	2000 Contingency forecasts for United States: Forecast base	Forecast range: Low	Forecast range: High	Probable
Transportation	1,250	2,500	1,500	2,500	2,000
Coating and plating	1,745	2,200	1,500	2,200	2,000
Batteries	620	1,700	1,700	5,000	3,000
Paints	1,120	2,200	1,700	2,500	2,000
Plastics and synthetic products	995	2,800	2,000	3,000	2,500
Other	498	1,300	900	2,000	1,200
Total	6,228	---	9,300	17,200	12,700

Figure IV-4 shows Stanford Research Insitute's projections of cadmium and zinc consumption to the year 2000. It should be noted that the slopes of both lines are equal and, therefore, the projections are parallel. Figure IV-4 yields an approximate U.S. demand of 10,000 tons in 1985 and 14,000 tons in 2000. These figures fall within the range of the predictions made by the Bureau of Mines as shown in Tables IV-7 and IV-8.

Estimates indicate that the United States has a reserve of 180,000 short tons of cadmium. If domestic resources supplied the total U.S. demand, 89,000 short tons cumulative 1973-1985, one half of the cadmium would be exhausted by 1985 (reference [3], p. 9). Since domestic production satisfies about 40 percent of the demand, supplies should last well beyond 2000 if imports continue to satisfy about 60 percent of the demand.



KEY

C = Consumption
P = Production
SP = Secondary Production

Figure IV-4

SRI PROJECTIONS OF CADMIUM AND ZINC CONSUMPTION
(Source: Reference [14])

No new technological advances increasing cadmium demand were foreseen by Bureau of Mine commodity analysts [7]. However, technological developments using other materials and various techniques to protect metal may decrease future demands for cadmium. These potential substitutions of processes will be discussed below in the section on alternatives.

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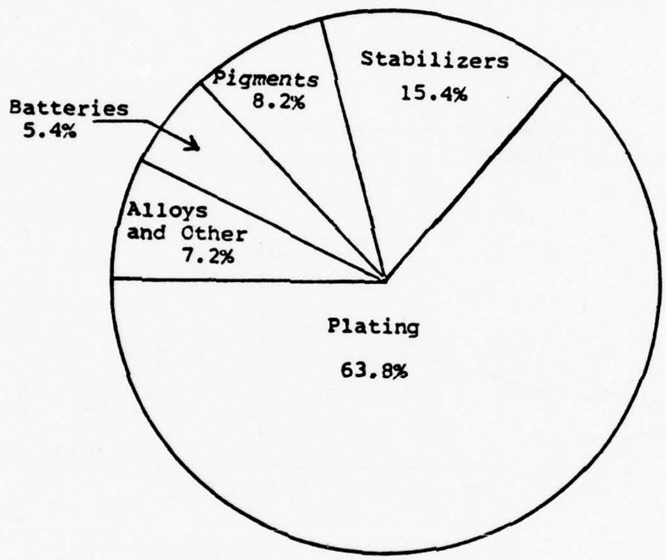
[14] Stanford Research Institute, *Strategic Resources and National Security, An Initial Assessment* (AD-A010 624), National Technical Information Service, Springfield, Virginia, April 1975.

6. *Impact on the Coast Guard*

Extensive analysis has been done concerning the usage of cadmium within the Department of Defense (DOD) [8]. This information can be used to give insights into Coast Guard consumption.

Figure IV-5 shows total DOD cadmium consumption in 1972. This includes direct usage in procurements for new construction, as well as indirect usage in procurements for replacement parts and other consumable supplies. The direct and indirect usage have been estimated at 35% and 65% of total DOD consumption [8].



Total = 620,000 pounds

Figure IV-5

TOTAL DOD CADMIUM CONSUMPTION BY END USE FOR 1972
(Source: Reference [8])

It has been estimated that approximately 30 to 40 percent of all Coast Guard procurements are made through the Defense Supply System and the Federal Supply System [15]. This fact, plus the obvious similarities in facilities used by the Coast Guard and the DOD, leads to a conclusion that Coast Guard utilization of cadmium should be roughly in proportion to DOD usage of the material.

The relative usages of cadmium by consumption category within DOD are also shown in Figure IV-5. The uses of cadmium for air, sea, and land units of DOD are shown in Figure IV-6. Plating is the dominant use.

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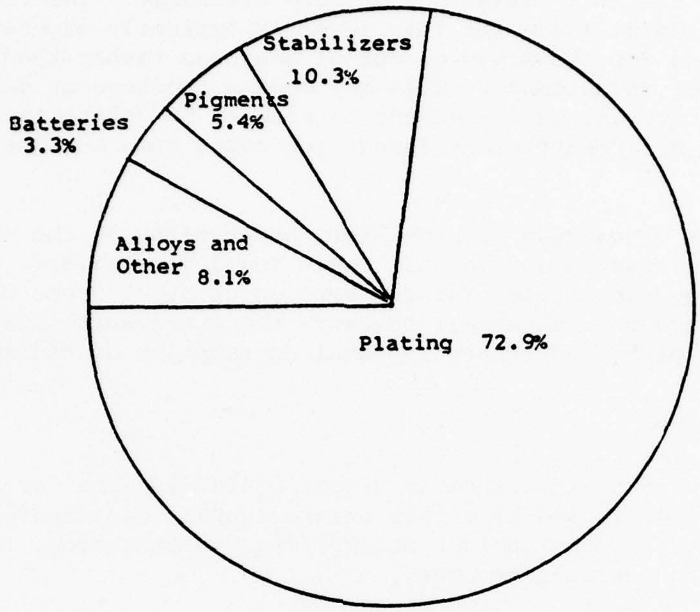
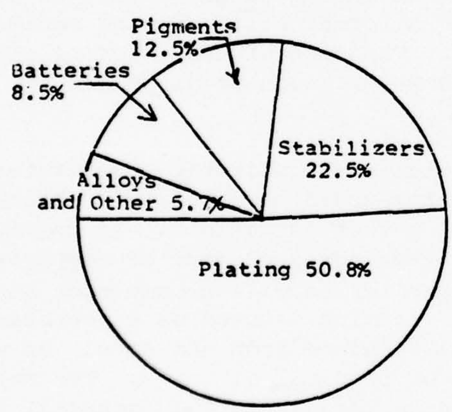
[15] Interview with CDR W.T. Troutman, Chief, Administrative and Review Branch of Headquarters Procurement Division (G-FCP/72), June 1977.

Air Unit Consumption of Cadmium per End Use



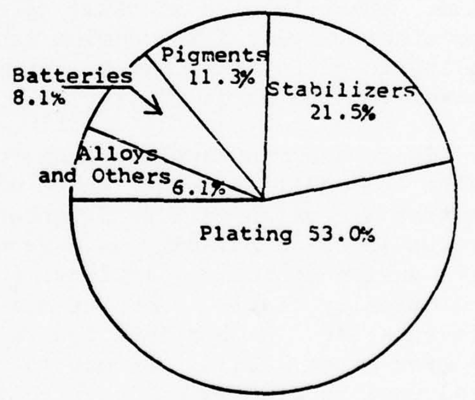
350,920 pounds

Sea Unit Consumption of Cadmium per End Use



125,860 pounds

Land Unit Consumption of Cadmium per End Use



143,220 pounds

AIR UNIT/SEA UNIT/LAND UNIT DOD USAGE OF CADMIUM
(Source: Reference [8])

The proposed 1977 EPA effluent guidelines are equivalent to 95% efficiency for the 1983 guidelines of zero discharge. The technology to reduce the cadmium losses to this level is extremely expensive. Small electroplating job shops may go out of business rather than make the required capital investments. This may mean a shortage in cadmium electroplating capacity unless the demand is reduced by shifts to new processes or materials or if sufficient larger job shops come on-line to take up the slack.

Shortages of cadmium or regulatory constraints on the use of cadmium could have diverse impacts on all Coast Guard facilities. Fortunately, there are many substitutes for the various uses. In some cases, cadmium will remain the best material; however, there are sufficient alternative materials to permit decreases in total consumption of cadmium.

7. *Alternatives*

There are several alternatives that could mitigate the effects of a cadmium shortage caused by either environmental constraints or materials unavailability. These include stockpiling, substitution, location of new resources, and resource recovery.

At present, the United States is maintaining a cadmium inventory in the national stockpile. The stockpile goal has increased 465 percent between 1975 and 1977 ([4], p. 45; [10], p. 26). This increase reflects a change in stockpile policy rather than an increased dependence on cadmium. There is also stockpiling on a less formal basis by zinc smelters and others involved in cadmium recovery. The size of the informal stockpiling is quite difficult to estimate; however, such holdings are not believed to be large [7,3].

There are many applications for cadmium where suitable substitutes exist and additional uses where substitutes could be developed. Trends in that direction will be dependent upon market conditions. If cadmium prices increase markedly as a result of the increased cost of complying with environmental regulations, then substitution will become much more economically viable. For the most part, cadmium is used as a corrosion preventative. Such a function is necessary since iron and steel, as well as many other metals, corrode in marine or tropical climates. The material used to provide such protection can be varied, but, in general, the equipment cannot be economically modified to function without corrosion protection of some sort.

A Government-industry workshop was held in October 1977 [16] at the National Bureau of Standards to discuss alternatives to cadmium electroplating for corrosion protection. Several of the processes involve

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[16] National Bureau of Standards, Summary of Abstracts: Government-Industry Workshop on Alternatives for Cadmium Electroplating in Metal Finishing, October 4-6, 1977.

technological innovations such as: ion vapor-deposited aluminum, chloride zinc plating, and manganese pressure phosphate coatings. Many of the substitute processes were also favorably reported in items of comparable economics and protection. Additionally, there are several alternative plating materials that can be applied using standard techniques such as zinc, tin-nickel, chromium, and phosphate.

Zinc's cost is only a fraction of cadmium's price. In 1977, zinc cost 34.4 cents/pound while cadmium cost $3.00 per pound [10]. Zinc also provides equal protection and comparable attractiveness. However, zinc can't be soldered well and forms a bulky corrosion product in tropical climates which can affect delicate instruments.

The use of cadmium as a pigment can, in most cases, be replaced by an organic or an inorganic compound. Inorganics include iron-oxide yellow, chrome yellow, molybdate orange, and ultramarine red. A partial list of the organics includes quinacridone red, anthrapyrimidine yellow, thioindigo red, and pyrayolone red.

Cadmium salts used as plastics stabilizers can be replaced by organotin compounds. The tin compounds are more efficient and can therefore be used in lower quantities than cadmium. However, the tin compounds are more expensive per pound of plastic produced, despite their greater efficiency. Other metal salts and salts of fatty acids (soaps) as well as other organic stabilizers can also be used to stabilize plastics.

Nickel-cadmium batteries can be replaced by conventional lead-acid batteries. Lead-acid batteries are cheaper and are more energy-efficient, but nickel-cadmium cells are superior in all other respects including energy density and temperature tolerance. Other batteries are being developed that show promise in specialized applications such as in submersibles, arctic buoys, and portable electronic equipment. An example is the lithium inorganic electrolyte cell [17].

The location of new cadmium resources can involve prospecting for cadmium directly, increasing the efficiency of cadmium recovery, or recycling cadmium-containing products. Utilizing present technology, the cost of recovery of cadmium from its ores is extremely expensive. No new technology is expected in the immediate future to make such processes more economical. However, cadmium recovery rates can be increased substantially via improved technology. Recovery rates vary from 14 pounds/ton of slab zinc in the United States to about 3 pounds/ton in foreign smelters. Obviously, more efficient recovery processes would increase cadmium supplies. As environmental regulations become stricter, and come into use in developing countries, more cadmium will be recovered and recycled to keep from violating pollution guidelines. Zinc miners

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[17] Hirschfeld, F., Electrochemical energy conversion. Part 2. Utilities, marine and space applications, *Mechanical Engineering* 99(7):28-34, July 1977.

presently receive no compensation for the cadmium content of zinc ores, although cadmium is a valuable source of revenue to zinc smelters. A revision of this procedure may also extend cadmium supplies.

Recycling of cadmium is presently economically feasible only in the case of batteries, and with some alloys and industrial wastes. Figure IV-7 illustrates the estimated level of dissipation of many metals after the initial use. It can be seen that almost 100 percent of the cadmium is lost after initial use. Current estimates indicate that 50 percent of the cadmium currently dissipated could be technically, though uneconomically, recovered. The other 50 percent is dissipated beyond recovery in such applications as pigments and plastics stabilizers.

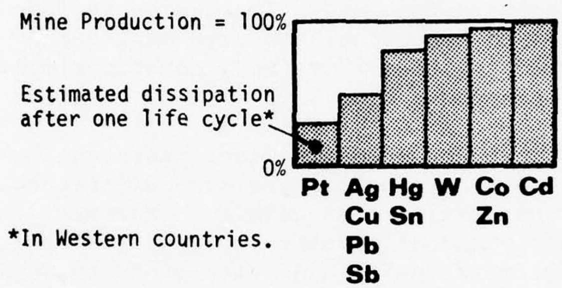


Figure IV-7

ESTIMATED LEVELS OF METAL DISSIPATION
(Source: Reference [1])

The use of cadmium in nickel-cadmium and silver-cadmium oxide batteries would not significantly dissipate cadmium. Spent cells could be recycled and the cadmium removed from manufacturing plant wastes to aid in extending existing cadmium resources. Other dissipative uses will probably be cut back through either environmental or economic constraints.

8. Conclusions

- Cadmium is a critical material for the Coast Guard whose availability is somewhat vulnerable due to a high level of import dependence and to a high susceptibility to regulatory control by the EPA.

- Coast Guard utilization of cadmium is in proportion to DOD use in plating, pigments, stabilizers, batteries, and alloys. There is no Coast Guard-peculiar use.

- No indications of past shortages of cadmium were identified during this study. Cadmium is presently stockpiled, and resources should last well beyond the year 2000.

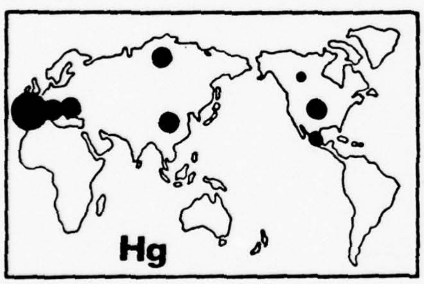
- If EPA regulations reduce the use of cadmium, there are a number of substitutes available for many but not all of its uses.

B. *MERCURY*

Mercury, or quicksilver, is a silvery-white metal that exists in a liquid state at room temperatures. The unique properties of mercury make it valuable for several applications. Its properties include: liquidity at ordinary temperatures, high surface tension, uniform volume expansion, good electrical conductivity, an ability to alloy readily, high density, chemical stability, and toxicity of its compounds [18]. The early uses of mercury were primarily medicinal and date back to the 16th century. Presently it is used to manufacture alkalies and chlorine, in electrical applications, as preservatives and toxicants in paints, instrument manufacture, in dental supplies, in pharmaceuticals, and in formation of catalysts [19]. The Coast Guard uses mercury in all of these forms.

1. *Sources and Uses*

Although mercury is found in approximately 25 minerals, almost all mercury is obtained from its sulfide called cinnabar. Figure IV-8 shows the worldwide distribution of mercury. Small amounts of mercury are recovered at limited gold mining and zinc smelter operations from process residues having a high mercury content. The most common method of mercury recovery involves crushing the ore and then roasting it in a furnace. The mercury vapor is then condensed, yielding a product that is over 99.9% pure.



Dot indicates country, not location of mine. Dot area is proportional to size of reserves in 1975, e.g.:

- 5% of world total
- 10% of world total
- 40% of world total

Reserves <2% of total are not shown.

Figure IV-8

LOCATION OF MAIN MERCURY RESERVES
(Source: Reference [1])

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[18] National Materials Advisory Board, *Trends in Usage of Mercury*, NMAB-258, National Academy of Sciences, Washington, D.C., September 1969.

[19] Interview with Mr. Harold Drake, Commodity Analyst, Bureau of Mines, Washington, D.C., 23 March 1978.

The components and distribution of domestic supply and demand of mercury are shown in Figure IV-9.

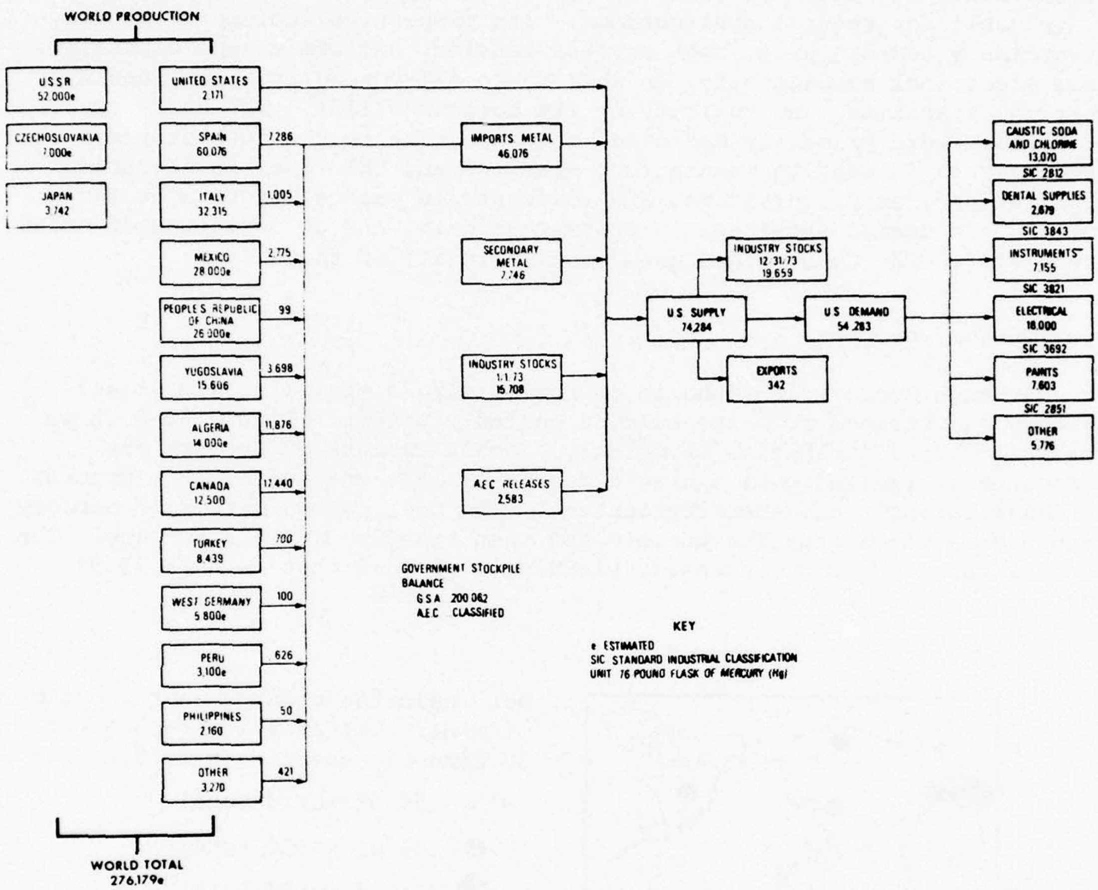

Figure IV-9

MERCURY SUPPLY-DEMAND RELATIONSHIPS—1973
(Source: Reference [20])

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[20] U.S. Department of the Interior, Bureau of Mines, Mercury - A Chapter from Mineral Facts and Problems, 1975 Edition, Preprint from Bulletin 667, U.S. Department of the Interior, Washington, D.C., 1975.

Mercury's major use at present is in electrical apparatus manufacture, which accounted for approximately 47 percent of the 1977 estimated consumption. Table IV-9 provides a comparison of end uses between 1977 consumption and average 1964-1973 consumption. Total consumption actually varies little between the 1964-1973 averages and the 1977 figures. However, the uses have changed considerably in some cases. Use of mercury as a biocide in the pulp and paper industry, and in amalgamation to recover gold were both discontinued in 1971 [21]. Methyl mercury was banned by the U.S. Department of Agriculture as a fungicide on seed grain. The increased use of mercury by the battery industry accounts for the demand remaining constant while actual use in some categories declined.

Table IV-9

1977 DOMESTIC CONSUMPTION OF MERCURY COMPARED WITH 1964-1973 AVERAGE CONSUMPTION BY END USE
(Sources: References [10,21])

Use	Percentage of Total		Quantity (in 76-pound flasks)	
	1964-1973	1977	1964-1973	1977[a]
Electrical apparatus	26.5	47	17,311	30,879
Production of caustic soda and chlorine	34	16	22,261	10,512
Mildew-proofing paint	13.2	13	8,655	8,541
Industrial and control instruments	11.2	9	7,295	5,913
Other applications	15.1	15	9,784	9,855
Total			65,306	65,700

[a]Estimated quantity.

The Federal Government has included mercury in the national stockpile. At present, there are 191,304 flasks of mercury on hand [10]. This represents a level that is 354 percent above the goal of 54,004 flasks. The General Services Administration (GSA) released 110,888 flasks between 1963 and 1974 from surplus government stocks. The Atomic Energy Commission (AEC) accounted for 72,500 flasks when it declared them surplus in 1964. No releases from government stocks occurred in 1976 or 1977.

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[21] Goeller, H. E., and A. M. Weinberg, The age of substitutability: What do we do when the mercury runs out?, *Science 191*(4228):683-689, February 20, 1976.

2. *Past Shortage Experience*

No indications of past shortages could be identified during the course of this study [22].

3. *Historical Trends*

Table IV-10 displays the characteristics of domestic supply and demand of mercury from 1964 to 1974.

Table IV-10

MERCURY DOMESTIC SUPPLY-DEMAND CHARACTERISTICS, 1964-1974
(Source: Reference [20])

(76-pound flasks)

	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974[p]
World production:											
United States	14,142	19,582	22,008	23,784	28,874	29,640	27,296	17,883	7,333	2,171	2,189
Rest of world	240,991	248,291	242,986	208,289	230,820	259,627	256,718	282,751	270,251	274,008	262,286
Total	255,133	267,873	264,994	232,073	259,694	289,267	284,014	300,634	277,584	276,179	264,475
Components of U.S. supply:											
Domestic mines (primary)	14,142	19,582	22,008	23,784	28,874	29,640	27,296	17,883	7,333	2,171	2,189
Secondary	7,519	14,906	8,535	10,696	10,570	10,573	7,348	10,899	12,139	7,746	5,940
Government release[1]	17,000	31,764	7,865	11,454	23,810	3,077	703	5,767	512	2,583	2,353
Imports, general	41,107	17,838	34,757	23,899	23,956	30,848	21,672	29,750	29,179	46,076	52,102
Industry stocks, Jan. 1	12,181	17,362	20,386	20,076	18,277	22,907	22,692	16,554	16,862	15,708	19,659
Total U.S. supply	91,949	101,452	93,551	89,909	105,487	97,045	79,711	80,853	66,025	74,284	82,243
Distribution of U.S. supply:											
Industry stocks, Dec. 31	17,362	20,386	20,076	18,277	22,907	22,692	16,554	16,862	15,708	19,659	22,298
Exports, including reexports	384	8,037	833	3,102	7,599	615	4,703	7,232	963	342	466
Industrial demand	81,354	73,560	71,509	69,517	75,422	77,372	61,503	52,257	52,907	54,283	59,479
Apparent surplus (+), deficit (−) supply[2]	−7,151	−531	+1,133	−987	−441	−3,634	−3,049	+4,502	−3,553	----	----
U.S. demand pattern:											
Caustic soda and chlorine	9,572	8,753	11,541	14,306	17,453	20,720	15,011	12,154	11,519	13,070	16,897
Dental supplies	5,068	3,439	2,133	2,386	3,079	2,880	2,286	2,361	2,983	2,679	3,024
Instruments	9,651	10,086	7,294	7,459	7,978	6,655	4,832	4,871	6,541	7,155	6,202
Electrical	17,138	18,402	17,638	16,223	19,630	18,490	15,952	16,885	15,553	18,000	19,678
Paints	6,516	8,466	8,929	7,178	10,566	9,730	10,347	8,605	8,222	7,603	6,813
Agriculture	3,144	3,116	2,374	3,732	3,430	2,689	1,811	1,477	1,836	([3])	([3])
Pharmaceuticals	335	418	232	283	424	712	690	682	578	([3])	([3])
Plastic and synthetic products	656	924	1,932	2,489	1,914	2,958	2,238	1,012	800	([3])	([3])
Other	[4]29,274	19,956	19,436	15,461	10,948	12,538	8,336	4,210	4,875	5,776	6,865
Total U.S. industrial demand	81,354	73,560	71,509	69,517	75,422	77,372	61,503	52,257	52,907	54,283	59,479
Total U.S. primary demand (industrial demand less secondary)	73,835	58,654	62,974	58,821	64,852	66,799	54,155	41,358	40,768	46,537	53,539

[p] Preliminary
[1] Includes mercury transferred to other Government agencies
[2] Mainly indicates changes in industry stocks
[3] Included under other
[4] Includes Government laboratory use of 15,746 flasks in 1964

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[22] Interview with Mr. Harold Drake, Commodity Analyst, Bureau of Mines, Washington, D.C., 23 March 1978.

Long-term trends of production, consumption, and prices of mercury are shown clearly in Figure IV-10.

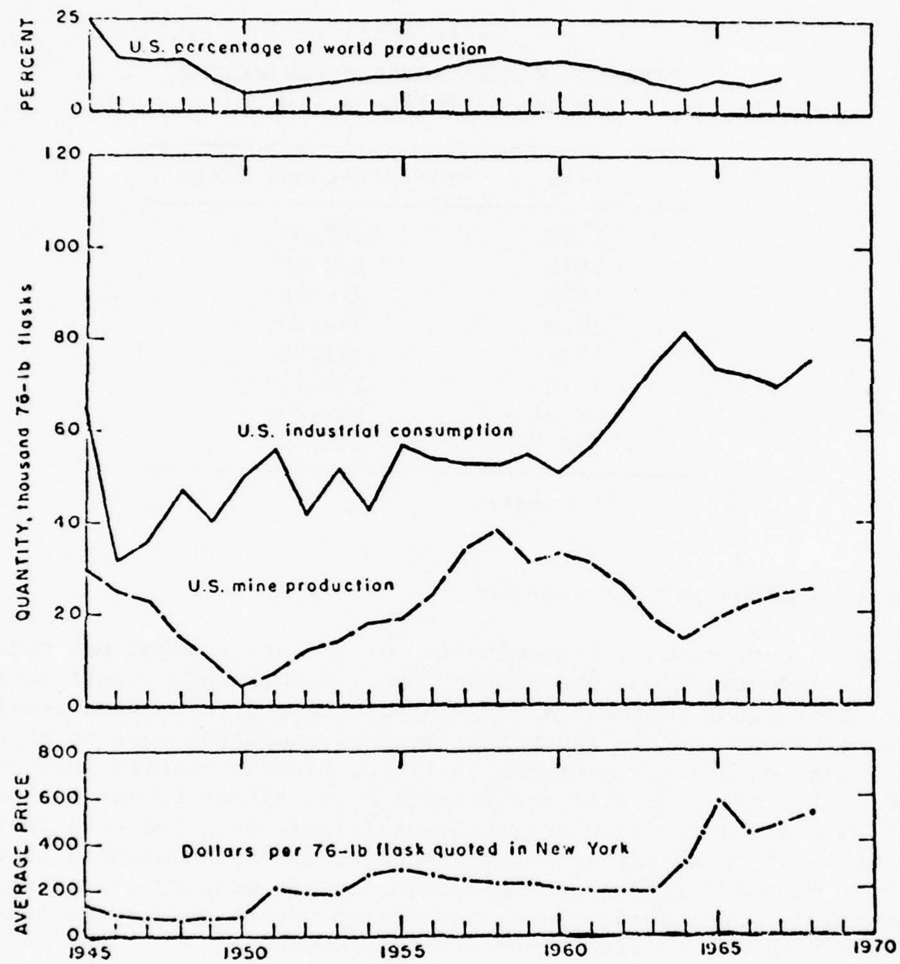

Figure IV-10

TRENDS IN PRODUCTION, CONSUMPTION AND PRICE OF MERCURY
(Source: Reference [18])

Recent price information including the current estimate for 1977 is provided in Table IV-11. Prices for 1977 show a moderate increase over 1976 levels, thus reversing the trend of continually decreasing prices established in past years.

Table IV-11

TIME-PRICE RELATIONSHIP FOR MERCURY
(Sources: References [10,20])

Year	Price/76-pound flask
1970	$407.80
1971	292.40
1972	218.30
1973	286.20
1974	281.70
1975	158.12
1976	121.30
1977[a]	145.00

[a]Estimate.

4. *Factors Affecting Consumption*

Concern over mercury contamination of the environment has caused considerable investigation into mercury and its compounds, their environmental and ecological impacts, and the health hazard to workers handling the substance. Research has shown that mercury compounds have no known metabolic function, and its presence in living tissues results from contamination [23]. The source of contamination can either be natural or a result of man's activity. Presently, available data indicate that approximately 35 to 40 percent of the mercury in the atmosphere is the result of man-made emissions. Although oceanic mercury levels appear to be essentially unchanged, freshwater and estuarine mercury burdens have increased from two to five times pre-man levels.

The toxicity of mercury and its compounds, the fact that it is nonbiodegradable and is concentrated in food chains of carnivorous species, and the incomplete data related to chronic, low-level exposures have led to the imposition of limits on mercury discharged into the environment. Maximum levels have also been set for the presence of mercury in food and treated water [24]. Included in these regulations are the Federal Water

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[23] National Academy of Sciences, *An Assessment of Mercury in the Environment*, National Academy of Sciences, Washington, D.C., 1977.

[24] Barrett, Bruce R., Controlling the entrance of toxic pollutants into U.S. waters, *Environmental Science and Technology 12*(2):154-162, February 1978.

Pollution Control Act of 1972 (P.L. 92-500) Section 307(a); the Toxic Substances Control Act of 1976 (P.L. 94-469); the Clean Air Act of 1963 (P.L. 88-206) with Amendments 1965, 1966, 1967, 1970, and 1977; the Safe Drinking Water Act of 1974 (P.L. 93-523); the Resources Conservation and Recovery Act of 1976 (P.L. 94-580); and National Institute for Occupational Safety and Health criteria documents [25].

5. *Supply and Demand Projections*

Table IV-12 provides a forecast of worldwide mercury demand for the years 1985 and 2000, based upon 1973 consumption. Cumulative demand through the year 2000 is also indicated. The economic forecasting indicators of total population growth and gross national product increase were applied to 1973 consumption data to obtain the forecast base for 2000.

Table IV-12

SUMMARY OF FORECASTS OF U.S. AND REST-OF-WORLD MERCURY DEMAND, 1973-2000
(Source: Reference [20])

(76-pound flasks)

	1973	2000 Forecast range		Probable		Probable average annual growth rate 1973-2000 percent
		Low	High	1985	2000	
United States: Metal:						
Primary	[1]46,537	32,000	66,000	53,000	47,000	[1]-0.8
Secondary	7,746	7,000	16,000	9,000	11,000	1.3
Total	[1]54,283	39,000	82,000	62,000	58,000	-.4
Cumulative (primary)	----	1,190,000	1,670,000	670,000	1,420,000	----
Rest of world: Metal:						
Primary	166,000	127,000	285,000	190,000	222,000	1.1
Secondary	5,000	3,000	15,000	8,000	15,000	4.2
Total	171,000	130,000	300,000	198,000	237,000	1.2
Cumulative (primary)	----	3,950,000	5,985,000	2,140,000	5,240,000	----
World: Metal:						
Primary	[1]212,537	159,000	351,000	243,000	269,000	[1].7
Secondary	12,746	10,000	31,000	17,000	26,000	2.7
Total	[1]225,283	169,000	382,000	260,000	295,000	.8
Cumulative (primary)	----	5,140,000	7,655,000	2,810,000	6,660,000	----

[1] *Calculated from a U.S. 20-year primary demand trend of 57,640 flasks for 1973.*

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[25] DHEW, National Institute for Occupational Safety and Health, *Criteria for a Recommended Standard--Occupational Exposure to Mercury*, U.S. Government Printing Office, Washington, D.C., 1973.

Table IV-13 breaks U.S. demand for the year 2000 into end use categories. Certain contingency assumptions, including technological and economic shifts, and social and political impacts which would tend to increase or decrease demand, were applied to the forecast base.

Table IV-13

PROJECTIONS AND FORECASTS FOR U.S. MERCURY DEMAND BY END USE, 1973 AND 2000
(Source: Reference [20])

(76-pound flasks)

End use	1973	2000			
		Contingency forecasts for United States			
		Forecast base	Forecast range		Probable
			Low	High	
Caustic soda and chlorine	13,070	33,000	10,000	20,000	15,000
Dental supplies	2,679	3,300	2,000	4,000	3,000
Electrical	18,000	22,000	20,000	30,000	25,000
Instruments	7,155	8,900	4,000	9,000	5,000
Paints	7,603	9,400	0	11,000	5,000
Other	5,776	7,200	3,000	8,000	5,000
Total	54,283	----	39,000	82,000	58,000

Table IV-14 indicates the forecast of U.S. mine production in the years 1985 and 2000. Comparing the domestic production estimates with demand projections for the United States in Tables IV-12 and IV-13 indicates that the United States will not be self-sufficient in mercury by the year 2000.

Table IV-14

FORECAST U.S. MERCURY MINE PRODUCTION
(Source: Reference [20])

(76-pound flasks)

	1973	2000				
		Forecast base	Forecast range		Probable	
			Low	High	1985	2000
Mine production	2,171	15,000	15,000	30,000	25,000	25,000
Mine production, cumulative	----	----	400,000	730,000	220,000	600,000

Figure IV-11 illustrates another projection of U.S. consumption. The projected requirement of 78,000 76-pound flasks is toward the upper limit of the 82,000 76-pound flasks shown in Table IV-13. The relationship between production and secondary production for 1950 to 1970 is also shown.

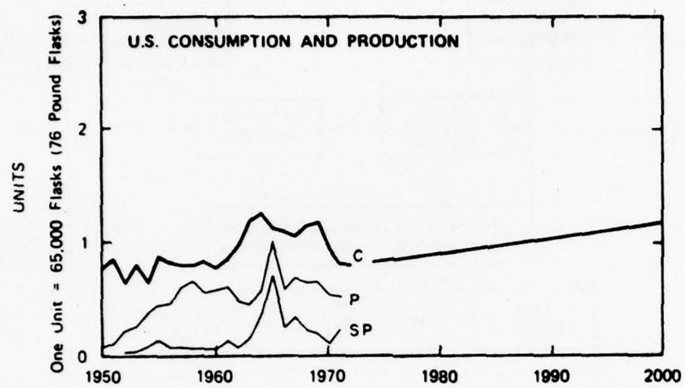

Figure IV-11

MERCURY CONSUMPTION PROJECTED IN 2000
(Source: Reference [14])

6. *Impact on the Coast Guard*

Mercury consumption within the Coast Guard is insignificant compared to national consumption. The uses parallel domestic uses. No special consumption was identified for Coast Guard-peculiar usage.

At present, substitutes exist for most uses of mercury; therefore, a total lack of mercury would not have more than a transitory impact on the Coast Guard. There would be some problems involved during transitions to the various substitutes, but no long-lasting effects. Since mercury would probably not be cut off at once but rather gradually, no problems are foreseen. Part of the impact of EPA's regulation of mercury has passed, and for the most part industry has adjusted without major disruptions.

7. *Alternatives*

The alternatives that would have a mitigating effect on a shortage of mercury include: stockpiling, recycling, and substitution. The Federal Government has been maintaining an inventory of mercury in the national stockpile.

The recycling of mercury in the United States accounted for 2,700 flasks, or about 4 percent of the domestic consumption. Sources of secondary, or recycled, mercury included used instruments, batteries, dental amalgams, and industrial scrap and residues. Figure IV-12 illustrates the flow of mercury scrap within domestic industries.

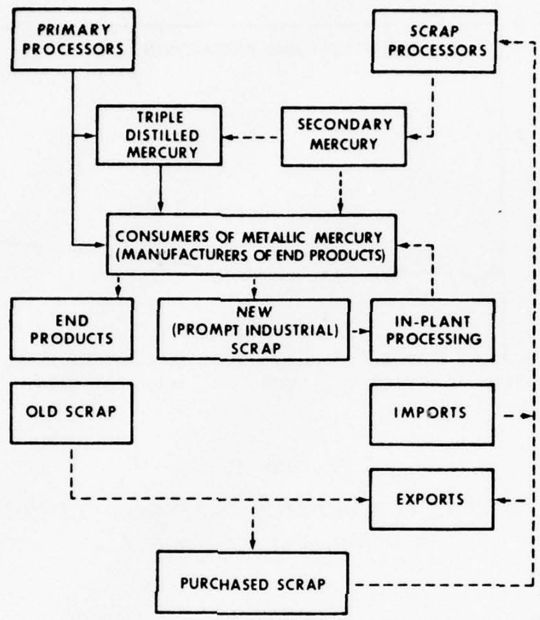

Figure IV-12. MERCURY SCRAP FLOW
(Source: Reference [20])

The decreased prices illustrated in Table IV-11 during the 1970's made recovery of mercury from low-grade scrap uneconomical. However, the increased effort to eliminate mercury discharges to the environment has resulted in enough mercury recovery to offset this decrease in supply. Technically, all mercury can be recovered from mercury-cell plants, electrical apparatus, and control instruments, upon the scrapping of such facilities or equipment. The dissipative uses of mercury, such as biocidal paints, antiseptics, catalysts, dental amalgams, and fungicides, are somewhat susceptible to reduction through pressure to eliminate mercury discharges into the environment.

Substitution is presently being practiced to eliminate worker exposure to mercury and to prevent discharges to the environment. The major use of mercury is in the production of electrical apparatus such as batteries, mercury-vapor lights and fluorescent lamps, and switches. While the mercury used in these applications is essential, other systems can be substituted that do not require mercury. Lithium batteries and zinc-MnO_2-

graphite dry cells make acceptable substitutes for the mercury cell and the zinc-air cell which require mercury to reduce hydrogen overvoltage at the anode. The lithium-iodide cell, a solid-state battery with no liquid components, delivers from 2 to 200 volts. It requires replacement only once every 10 years in pacemaker applications, as compared to every two years for mercury cells [26]. Technological developments for batteries are usually proprietary; thus, information regarding such new innovations is very difficult to assess.

Other electrical uses for mercury can be substituted directly. There is some loss of efficiency in the substitution of alternative lighting systems for mercury-vapor lamps [20]. Electronic thermometers and mechanical diaphragms which replace mercury thermometers and flow meters, respectively, are two examples of solid-state instruments that are replacing mercury instruments to avoid occupational mercury exposure.

Biocidal and antifouling marine paints can be produced with organotin compounds, copper oxide, and plastics as substitutes for mercury. The Environmental Protection Agency's regulations are behind this effort to limit mercury emissions.

The production of caustic soda and chlorine is extremely important to the paper industry [27]. Both chemicals are produced by mercury cells. The diaphragm cell is a substitute and was recently evaluated at a large paper mill [28]. Results according to mill officials are positive, and the plant's mercury cells will be shut down in 1978.

Substitutes for the remaining uses of mercury, pharmaceuticals and dental amalgams, are available. Sulfur drugs, iodine, and other disinfectants are available to replace mercury as an antiseptic. Ceramics, metal powders, plastics, and stainless steel inlays are acceptable substitutes for dental amalgams. Some resistance to this substitution has been noted because mercury tin/silver amalgams are so widely used and the techniques are well proven.

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[26] Versar, Inc., *Assessment of Industrial Hazardous Waste Practices: Storage and Primary Battery Industries*, Versar, Inc., Springfield, Virginia, 1975.

[27] National Commission on Supplies and Shortages, *The Commodity Shortages of 1973-1974, Spot Shortage Conditions in 1973-1974: The Pulp and Paper Industry Experience*, U.S. Government Printing Office, Washington, D.C., August 1976.

[28] Hoyer, Hans, Membrane-cell chlor-alkali system proves successful at Marathon mill, *Pulp and Paper 52*(1):144-145, January 1978.

8. Conclusions

- Mercury is a critical material for the Coast Guard that is somewhat vulnerable to foreign dependence and more vulnerable to environmental regulation.

- Coast Guard usage of mercury is similar to U.S. domestic use, for electrical applications, instruments, dental supplies, pharmaceuticals, and preservatives and toxicants in paint. There is no Coast Guard-peculiar use.

- No indications of past shortages of mercury were identified during this study. Mercury is presently stockpiled and supplies are adequate.

- EPA regulations have induced shifts away from the use of mercury. There are substitutes available for each use.

C. *JEWEL BEARINGS*

Jewel bearings are specialized products used in precision measuring instruments, radio and television transmitting equipment, automatic controls, photographic equipment, and watches and clocks. Jewel bearings offer an extremely low coefficient of friction and are used in applications where extremely good wear and shock resistance, as well as minimal expansion and contraction due to temperature changes, are required. Precision instruments and timekeeping devices account for almost the entire demand for jewel bearings.

1. *Sources and Uses*

Jewel bearing consumption in the United States is shown by Standard Industrial Code (SIC) in Table IV-15.

Table IV-15

JEWEL BEARING CONSUMPTION IN THE UNITED STATES FOR 1975
(Source: Reference [29])

SIC	Industry	Quantity
3873	Watches, clocks & parts	26,277,000
3823	Measurement & control instruments	2,353,000
3829	Measurement & controlling devices n.e.c.	2,190,000
3825	Instruments for measuring electricity	830,000
3811	Engineering & scientific instruments	768,000
3662	Radio & TV transmitting equipment	187,000
3861	Photographic equipment	43,000
3915	Jewelers' findings & materials	negligible
	Total	68,623,000

Because of their critical nature in many Department of Defense weapon systems and operating units, jewel bearings are maintained in the national stockpile. There were 62,986,683 jewel bearings stockpiled as of 30 June 1975 [4].

There is currently only one complete producer of jewel bearings in the United States. At previous times, such as during World War II, domestic producers supplied large quantities of jewel bearings to the Federal Government. The William Langer Jewel Bearing Plant was established by the Government in 1953 to maintain a jewel bearing capability within the United States. In order to ensure the retention of essential production

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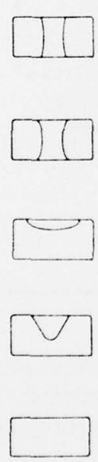
[29] Interview with Mr. Vernon Tvedt, Office of Business, Research and Analysis, Department of Commerce, Washington, D.C., March 1978.

capabilities, the Government has established the Armed Services Procurement Regulation (ASPR) and the Federal Procurement Regulations (FPR). Both regulations contain clauses requiring producers who are supplying equipment containing jewel bearings to the Government to obtain these bearings from the William Langer Plant. However, due to several factors affecting ASPR and FPR, including granted exceptions, noncompliance, limited enforcement, and requirements for purchase of William Langer jewels but not their use; the William Langer Plant produces only from 40 to 60 percent of the bearings used in U.S. Government-purchased products [30].

In the past, bearings were fabricated from natural gemstones, but now most are derived from synthetic sapphires and rubies. Synthetic sapphires are formed from pure aluminum oxide and are transparent. The addition of chromium oxide imparts a red color for greater visibility, and makes the gem a ruby instead of a sapphire. Treatment with an electric arc forms a carrot-shaped mass called a boule. This is then sliced into cubes which form the input of the bearing manufacturing process. Figure IV-13 illustrates some of the basic configurations produced at the facility. The basic forms illustrated in Figure IV-13 can be combined to produce 81 variations. Tolerances on hole size average about one 10,000th of an inch, but can be held to 25 millionths of an inch if required.



BAR HOLE: Hole sizes range from .0032 inch to .2500 inch.

OLIVE HOLE: Maximum olive radius is four times hole size.

CUP: Wide variety of cup radii and depths available.

VEE: "V" radius from .0020 inch to .0079 inch; "V" angle from 60 to 120 degrees.

ENDSTONE: Outside diameter .0080 inch to 1 inch; thickness .0030 inch to .1275 inch.

Figure IV-13. BASIC JEWEL BEARING FORMS
(Source: Reference [31])

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[30] Battelle Columbus Laboratories, *Analysis of Uses of Jewel Bearings in United States Government Products*, Battelle Columbus Laboratories, Columbus, Ohio, June 25, 1975.

[31] Company Brochure of William Langer Jewel Bearing Plant, Introductory Statement by General Services Administration, no date.

2. *Historical Trends*

The jewel bearing industry has declined in recent years due to the advent of solid-state electronics and other substitutes. The trend has been a decline in orders from the William Langer Plant. Figure V-14 shows the recent trend in domestic jewel bearings for watches and clocks, which account for 90 percent of jewel bearing use in the United States.

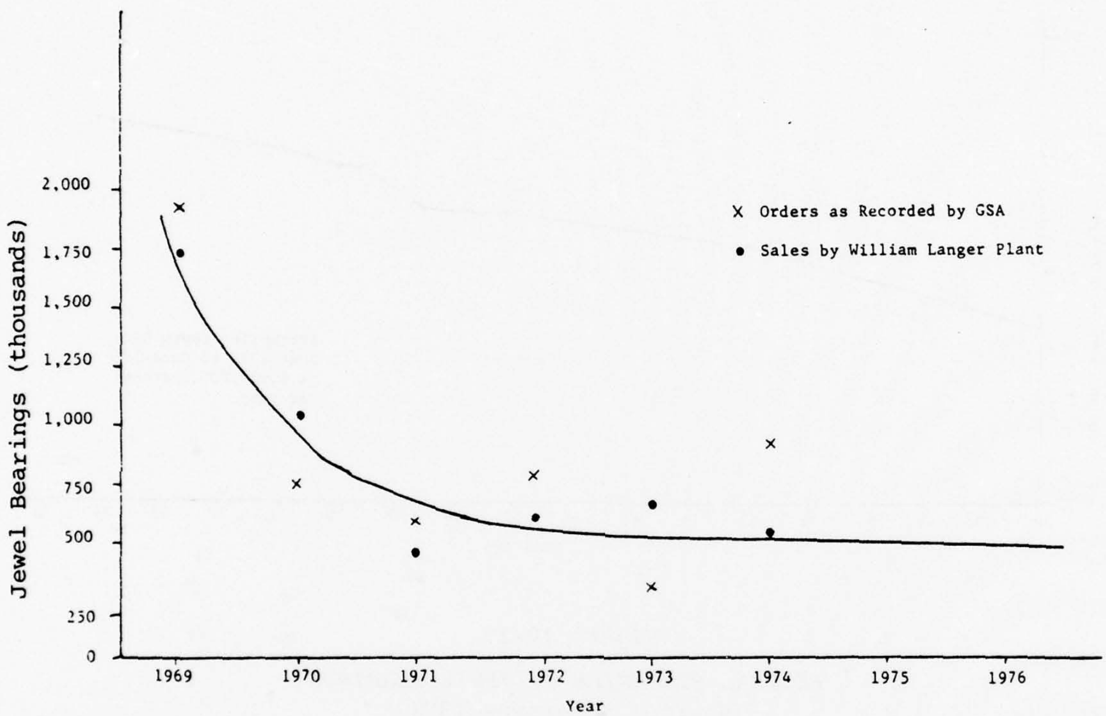

Figure IV-14

JEWEL BEARINGS FOR WATCHES AND CLOCKS (AIRCRAFT CLOCKS ***NOT*** *INCLUDED)*
(Source: Reference [30])

However, the stockpile growth rate is increasing, as shown in Figure IV-15. The stockpile goals promulgated by the Federal Preparedness Agency indicate a goal of 224,633,000 as of 1 October 1976 [32]. Such a goal requires almost a fourfold increase over the inventory of 30 June 1975 at 62,986,683.

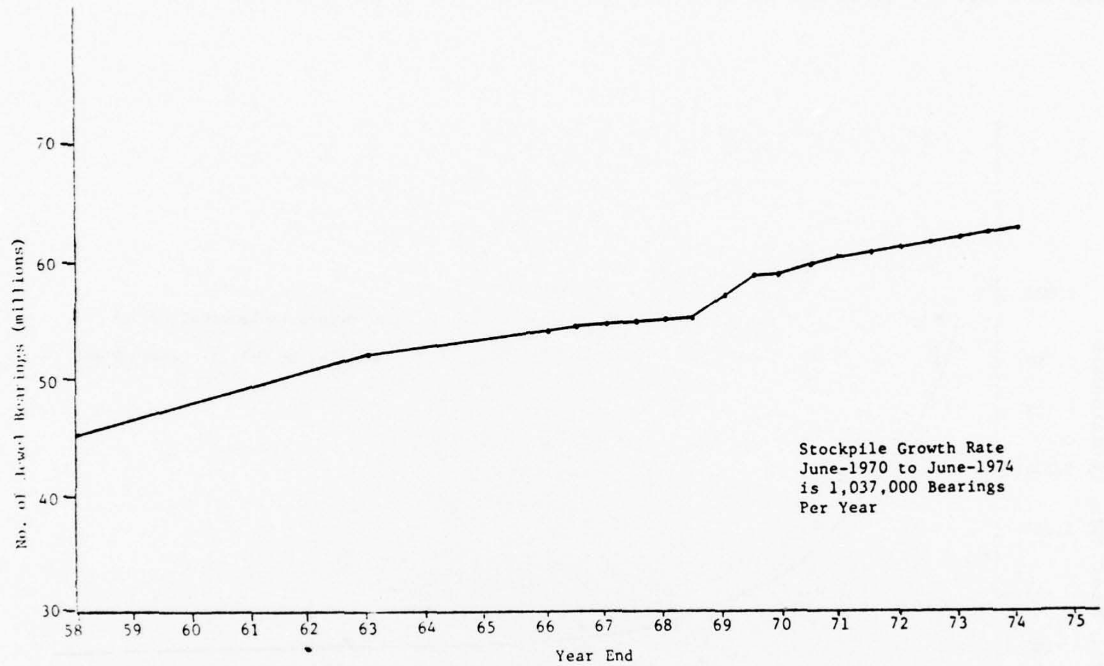

Figure IV-15

FEDERAL STOCKPILE OF JEWEL BEARINGS
(Source: Reference [30])

However, this increase does not necessarily indicate an increased need for jewel bearings, but indicates a change in the stockpile policy. The present goals are based on a three-year war; the change would necessitate a threefold increase from a one-year war supply. As of 30 March 1977, there were 64,457,000 bearings in the stockpile [33].

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[32] Federal Preparedness Agency, General Services Administration, Stockpile Goal Action 77-1, *Federal Register*, FR Doc 76-29473, 6 October 1976.

[33] Interview with Mr. Robert Mroczek, Federal Preparedness Agency, General Services Administration, Washington, D.C., 24 March 1978.

3. *Past Shortage Experience*

A shortage of jewel bearings was caused by World War II when sources in Europe were cut off [34]. Several domestic plants then began to produce jewel bearings and manufactured large quantities. However, after the war, when European sources were again available, domestic production ceased. At that point, no domestic sources existed. As a result of this lack, the William F. Langer Jewel Bearing Plant was established. It began operation in March of 1953. Originally the plant was operated by the Bulova Watch Company for the Department of Ordnance. Presently the General Services Administration manages the facility. Thus, in response to past shortages, the Federal Government is "stockpiling" the expertise required to produce jewel bearings as well as the bearings themselves.

4. *Potential Developments*

Trends in demand and supply of jewel bearings are estimated to remain stable, or actually decline [29,30]. Figures derived from Table IV-15 indicate that 91 percent of the national consumption of jewel bearings has been for watches and clocks. Recent developments in light-emitting diodes, liquid crystal displays, and timepieces not using mechanical movements (e.g., quartz) are causing the demand for jewel bearings to decrease. As technology advances and as the cost of products using alternatives to jewel bearings decreases, the demand for jewel bearings is also expected to decrease. Reliable, long-term projections for jewel bearing usage were not readily available, and Battelle noted that a long-term (10-year) forecast of the demand for jewel bearings would be of great value to the Federal Government.

5. *Impact on the Coast Guard*

The effect of a total lack of jewel bearings would be to cause minimal operational problems for the Coast Guard. There are several functional substitutes that could replace all Coast Guard uses of jewel bearings. While there would be no operational impairment, the transition could create some supply problems; these would occur only in cases where components containing jewel bearings required repair. Since the Coast Guard does not repair its own instruments, replacement of the equipment with a component not requiring jewel bearings would generally eliminate the problem.

The major use of jewel bearings by the Coast Guard is in aircraft instrumentation. Table IV-16 shows estimates of the numbers of such bearings in general aircraft instruments. A summary of the information in Table IV-16 indicates a low of 443 jewel bearings and a high of 666. Table IV-17 shows the Coast Guard inventory of aircraft and the estimated number of jewel bearings aboard.

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[34] Interview with Mr. Henry James, General Manager, William F. Langer Jewel Bearing Plant, Rolla, North Dakota, 10 April 1978.

Table IV-16

JEWEL BEARINGS IN INSTRUMENTATION
(Source: Reference [30])

Aircraft Navigation and Attitude Control	No. Jewel Bearings
Attitude Control Assembly	6-16
Attitude Indicating Sys.--Self-Contained	6-16
Auto-Pilot System	4-22
Compass System--B	4-8
Control Set-Approach Power	2
Course Indicator	2-8
Directional Gyro	0-8
Directional Gyro Compass System	0-8
Geomagnetic Compass System	0-8
Gyrosyn Compass	6
Gyro-Displacement, Pitch and Roll	0-8
Heading and Attitude Reference System	6-22
Inertial Navigation System	0-32
Integrated Flight Instrument System	18
Loran Set	6
Radio Magnetic Indicator	6
Three-Axis Rate Sensor	0-8
Vertical Gyro (Horizon Indicator)	4-8
VOR/LOC	6
Totals	76-216

Aircraft Electronic Systems	No. Jewel Bearings
Beacon Set Data	6
Control Radio Set	2
Direction Finder Group	2
Direction Finder Set	2
ESM	4
Heads-up Display	0-4
IFF Interrogator	2
Magnetic Compensator Group	2-4
Magnetic Detecting Set	2
Pilot Display System	0-6
Receiving Decoding Group	2
Recorder Group	6
Remote Frequency/Channel Ind.	2
Radar	
Altimeter Set	4-6
Beacon Receiver Set	6
Navigation Set (Doppler)	2
Set	8-10
Radio	
HF Communications Set	4
Navigation Set	2
Receiving Set	4
Tacan Navigation Set	8
UHF	4
VHF	2
Totals	76-92

(continued)

Table IV-16 (continued)

JEWEL BEARINGS IN INSTRUMENTATION

Aircraft General Instruments	No. Jewel Bearings
Accelerometer	2
Accelerometer Counting Group	8
Air Temperature Ind.	2
Airspeed Ind.	2
Airspeed/Mach meter	20
Altimeter	20-25
Altimeter-cabin press.	20-25
Altimeter Encoder	20-25
Altitude & Differential Press. Ind.	25
Ammeter	2-4
Angle of Attach Ind.	2
Azimuth Detector, Magnetic	8
Barometer Set	2-6
Bearing, Dist. Heading Ind.	4-10
CDS Oil Temp. Ind.	2
Clock	14-20
Compass, Magnetic Standby	2-8
Deicer Pressure Gage	2
Elapsed Time Clock	20
Flap Position & Rudder Ind.	2-4
Frequency Meter Ind.	2
Horizontal Situation Ind.	14-18
Hydraulic Brake Press.	2-4
Hydraulic Oil Qty. Ind.	2-4
Hydraulic Oil Press.	2-4
Hydraulic Rudder Press.	2
Liquid Oxygen Qty. Ind.	2
Oxygen Pressure Ind.	2
Pneumatic Suction Gage	2
Rate of Climb-Cabin Press.	4
Supply Air Duct Press.	2
Valve Position Ind.	2
Vertical Gyro-Horizon Ind.	0-8
Vertical Speed Ind.	4-6
Volt-Ammeter	2-4
Volt Meter	2-4
Yaw Damper Position Ind.	2
Totals	227-292

Aircraft Engine Instruments	No. Jewel Bearings
Air Mainfold Press.	2-4
Engine Duct Heat/Cool	2
Engine Gas Temperature Ind.	2
Engine Hours Timer	20
Engine Temperature	2
Engine Torque Ind.	2
Engine Vibration Ind.	4
Fuel Flowmeter Ind.	2-4
Fuel Press. Ind.	2
Fuel Quantity Ind.	2-4
Fuel Temperature Ind.	2
Gas Generator Tachometer Ind.	2
Oil Press. Ind.	2-4
Oil Quantity Ind.	2-4
Oil Temperature Ind.	2-4
Power Turbine Inlet Temp. Ind.	2
Pressure Ratio Ind.	2-4
Tachometer (Generator)	2
Tachometer	2
Totals	58-72

Table IV-17

COAST GUARD AIRCRAFT AND ESTIMATED JEWEL BEARINGS ABOARD
(Source: Reference [35])

Aircraft Type	Estimated Number of Jewel Bearings in Aircraft		Number of Aircraft in U.S. Coast Guard	Estimated Number of Jewel Bearings per Aircraft Type	
	Low	High		Low	High
HU-16	443	666	17	7,531	11,322
C-130	443	666	25	11,075	16,650
C-131	443	666	17	7,531	11,322
VC-4	443	666	1	443	666
VC-11	443	666	1	443	666
HH3F	195	482	38	7,410	18,316
HH52A	157	237	84	13,188	19,908
Total			183	47,621	78,850

The average of the number of jewel bearings used aboard each Coast Guard cutter and boat is estimated to be in the range of 12 to 24. The estimated number of jewel bearings on Coast Guard cutters and boats ranges from none aboard the smallest boats to 500 or more on the larger and more complex cutters [36]. Most of the bearings currently aboard Coast Guard vessels are found in precision clocks. Estimates of the number of jewel bearings used in the manufacture of systems, components, and instruments, for both ships and aircraft, varied considerably. They range from the high of 900 plus for some aircraft types noted in the Battelle study [30] to a low of zero for ships [37] and roughly 100 per aircraft [38]. To obtain an accurate tabulation of jewel bearings on board ships or aircraft, the manufacturer of each system and component would have to be identified. The manufacturers would then have to be surveyed regarding each component. This effort is beyond the scope of the present study, and the estimates provided here represent the best available information.

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[35] Interview with CDR R. Wehr, U.S. Coast Guard (G-EAE), Washington, D.C., 24 March 1978.

[36] Interview with Mr. A. E. Crout, Office of Engineering, U.S. Coast Guard, Washington, D.C., 24 March 1978.

[37] Interview with Mr. Emil Saul, U.S. Coast Guard, Supply Depot, Curtis Bay, Maryland, 3 April 1978.

[38] Interview with Mr. Perry Smith, U.S. Air Force, Aerospace Systems, Wright-Patterson Air Base, Dayton, Ohio, 10 April 1978.

Since the Coast Guard does not perform its own jewel bearing replacements, no inventory of jewel bearings is maintained by the Coast Guard. The movement of jewel bearings through industry and the military services is traced in Figure IV-16. The Coast Guard normally enters the system at the end use in the procurement of operational equipment. In some cases, purchase of individual instruments for replacement in currently owned systems includes jewel bearings. However, at no point could the actual purchase of individual bearings by the Coast Guard be identified.

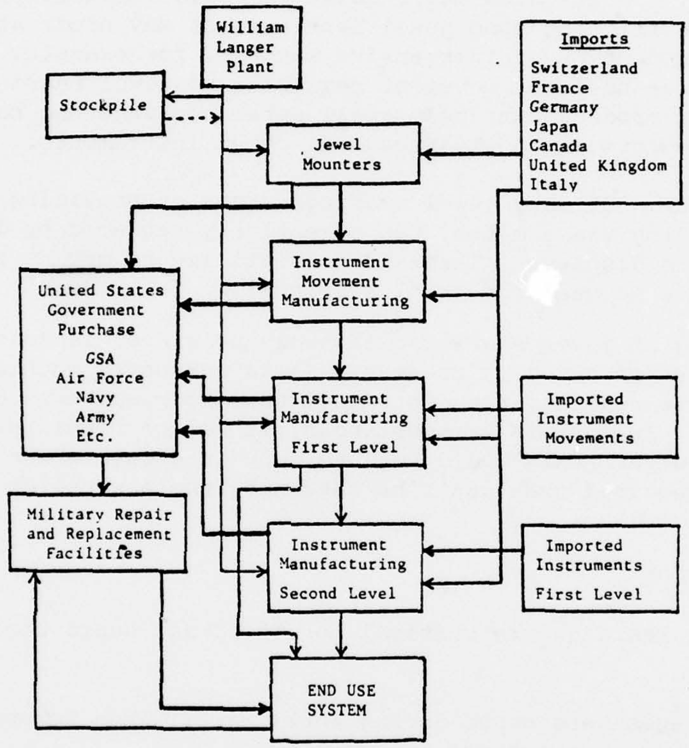

Figure IV-16. FLOW OF JEWEL BEARINGS IN INDUSTRY
(Source: Reference [30])

6. *Alternatives*

There are several alternatives that would prevent, or at least limit the severity of, a jewel bearing shortage. They include stockpiling, substitution of other materials, functional substitution, recycling, and redesign of instruments.

At present, the General Services Administration, through the Federal Preparedness Agency, maintains the national stockpile of which jewel bearings are a component. Coast Guard requirements could be filled from the

national stockpile either during a state of declared national emergency by the Administrator of the GSA, or during a period without a state of emergency by the President. Upon approval by the President, the material would be released for Coast Guard use. Since the stockpile began just after World War II, there have been 27 requests granted without declared states of emergency existing [33].

Other materials that can be substituted directly for jewel bearings include various alloys and metals in the form of ball or roller bearings and bushings. Substitutes may require periodic lubrication, may have slightly more friction than jewel bearings, or may erode at a more rapid rate. The production of inexpensive watches, for example, currently utilizes a pin-and-lever movement requiring no jewel bearings [39]. Several firms produce extremely small metal bearings and bushings for use in anemometers, gyrocompasses, and other instruments.

The function of many jewel bearings, that of providing an extremely accurate reading via a meter, can be entirely replaced by digital readouts and electronic displays. These methods utilize no moving parts at all and therefore have no need for jewel bearings.

Recycling of jewel bearings, although possible, is done only in a limited number of cases at present. It is currently much more economical to procure new bearings than to remove them from surveyed equipment for further use. In certain circumstances, it may be feasible to use recycled bearings; however, this would be done only in a case where a specific bearing is required that can't be obtained from a supplier in a reasonable time.

7. *Conclusions*

- Jewel bearings are critical for the Coast Guard because of foreign dependence.

- Shortages were noted during World War II when European, primarily Swiss, supplies were cut off.

- Coast Guard utilization of jewel bearings is limited to precision instruments and timekeeping devices. There is no Coast Guard-peculiar use.

- The Federal Government owns the only domestic factory for jewel bearings. Jewel bearings are stockpiled.

- Most applications for jewel bearings are being replaced with light-emitting diodes, liquid crystal displays, timepieces without mechanical movements, improved metal bearings, and solid-state electronic instruments with digital readouts.

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[39] Interview with Mr. David Lynn, Lynn Jewelers, Washington, D.C., 27 March 1978.

D. *ICEBREAKER PROPELLERS*

Two problems are apparent in the procurement of propellers for icebreakers. The first is the more visible and immediate problem of limited manufacturing sources. The second is the potential problem posed by limited materials availability.

The first problem, which is the shortage in the number of manufacturing sources, is caused by several factors including the reluctance of vendors to deal with exacting Coast Guard Military Specifications, the apparent high cost of small and sporadic orders, the difficulties in handling, casting, and machining the specialized material, and new environmental requirements on fabricating plants.

The second problem is potentially more directly linked to raw material scarcities. Icebreaker propellers are composed of several different combinations of materials, depending on when the original ship was designed and how recently the propeller was manufactured. Most of the alloys share the following elements: chromium, nickel, copper, tin, silicon, molybdenum, iron, and manganese. Certain of these metals are expected to be diminishing in supply in the future. These projected shortages may have some effect on small consumers of specialized alloys like the Coast Guard, by increasing the prices of both basic materials and finished products and by shifting the manufacturers' priorities for scarce materials allocation to their more stable, high-volume customers.

1. *Nature of the Problem*

The propellers used on Coast Guard icebreakers embody a complex technology. The materials that are used must meet exacting standards as to proportion, components, and allowable impurities. The processes used to give the propeller its final shape involve the casting of large amounts of alloys and precision machining [40].

Table IV-18 lists the military or American Society of Testing Materials (ASTM) specifications for the materials used to fabricate propellers.

Procurement of propellers for Coast Guard cutters has proved difficult in the past. The materials are quite difficult to work with, and specifications are very exacting. These combined factors make contractors hesitant to bid on Coast Guard projects. The situation is further complicated by the fact that the Coast Guard orders small quantities on a very irregular basis.

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[40] Interview with LT Robert W. Gulick, USCG, P.E. (G-ENE-4/64), Washington, D.C., January 1978.

Table IV-18

SPECIFICATIONS FOR PROPELLER CASTING MATERIALS
(Sources: References [40,41,42,43])

Title	Date of Issue	Chemical Composition
MIL-S-16993A-CL2 [41] (12-percent chromium)	25 November 1952	0.15% C(max), 1.0% Mn(max), 0.5% Si(max), 0.05% P(max), 0.65-1.0% Ni, 0.5-0.7% Mo, 0.05% S(max), 11.5-14.0% Cr
MIL-B-21230A-CL2 [42] (Superston 40)	29 July 1960	71% Cu(min), 11-14% Mn, 1.5-3.0% Ni, 2.0-4.0% Fe, 7.0-8.5% Al, 0.1% Si(max), 0.03% Pb(max), total others 0.50%(max)
ASTM-296-72 [43] (CA-6NM)		11.5-14.0% Cr, 0.4-1.0% Mo, 3.5-4.5% Ni, 0.06% C(max), 1.0% Mn(max), 0.04% P(max), 0.04% S(max), 1.07 Si(max)

During the procurement of blades for the WIND-R class from Avondale's foundry, there were several rejections due to pocketing and sand inclusions. There have also been some difficulties in the procurement of blades made of Superston 40 used in propellers for the GLACIER. The material was developed in England, but the process was utilized in the United States under an agreement with the developer. A Superston-40 propeller suffered a blade failure under normal service; a failure analysis identified minute chromium contamination during the original pouring as a major contributing factor. An extensive and successful engineering effort resulted in the development of a heat treatment process that allowed salvage of the remaining blades from that pouring. In the event of additional production of Superston-40 blades, a new specification will be necessary. The limitation in the current specification of total other elements at 0.50% (maximum) is insufficient. A specific limitation should be required for chromium.

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[41] MIL-S-16993A of 25 November 1952, with Amendment 1 of 1 December 1954.

[42] MIL-B-21230A(SHIPS) of 29 July 1960, with Amendment 3 of 18 March 1968.

[43] Sales brochure, ESCO, Inc., Portland, Oregon, describing CA-6NM, a stainless steel casting alloy, 1971.

2. *Materials Availability*

The problem of limited manufacturing sources may also be complicated by the decreasing availability of metals required for producing the stainless alloys required. At present, the importing of chromium-bearing materials satisfied 89 percent of the U.S. chromium demand [10]. Due to the critical nature of chromium, the U.S. national stockpile contains 3,353 tons of chromium-containing material and 575,522 tons of nonstockpile-grade chromium-containing material. The present stockpile goal calls for an additional 1,012 tons of chromium-containing materials as of November 1977.

The possible decrease in chromium availability will result from political considerations rather than from actual mineral scarcity as shown in Figure IV-17. The world reserves are indicated at nine to ten times the projected cumulative world demand to the year 2000.

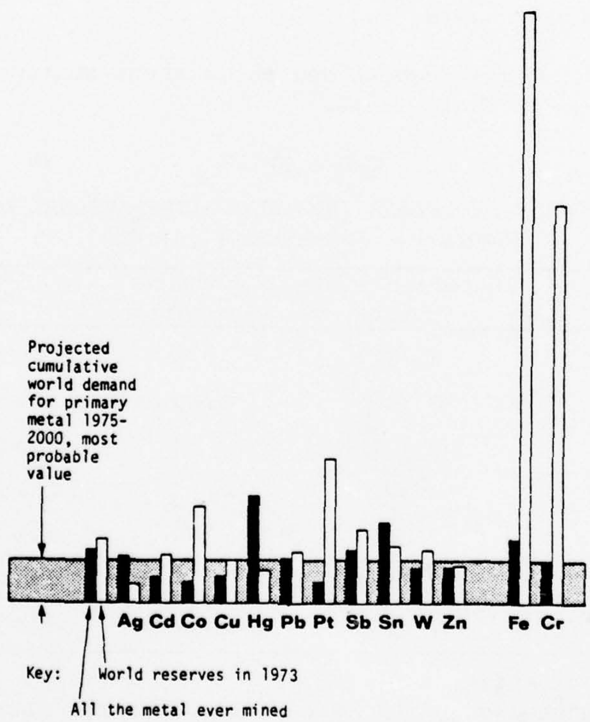

Figure IV-17

PROJECTED CUMULATIVE WORLD DEMAND
1975-2000 vs. CURRENT 1973 RESERVES
(Source: Reference [1])

Figure IV-17 indicates that chromium is a very abundant element. However, 98 percent of the world's identified resources, or 97 percent of the world's reserves, are located in Rhodesia and the Union of South Africa; the Soviet Union is the third largest potential source of chromite. With much of the world's resources and reserves being located in countries that may have political differences with the United States, our chromium supply is far from secure.

The Superston-40 propellers [42] also contain substantial proportions of copper. As indicated in Figure IV-17, the availability of copper will probably become restricted by the year 2000. Shortages in other elements required by icebreaking propellers do not appear likely by the year 2000.

3. *Past Shortage Experience*

To date, long lead times for procurements have been experienced although no actual shortages have occurred [40].

4. *Impact on the Coast Guard*

A list of existing icebreakers and the current status of icebreaking propellers are shown in Table IV-19.

Table IV-19

COAST GUARD ICEBREAKER PROPELLER INVENTORY (OPERATIONAL UNITS AND SPARES)
(Sources: References [44,45])

Cutters (No.)	Propellers/Unit (Total)	Spare Propellers	Material
POLAR Class (2)	3 (6)	2	CA-6NM
WIND-R (2)	2 (4)	Unknown[a]	12% Cr
GLACIER (1)	2 (2)	8	Superston 40[b]
MACKINAW (1)	3 (3)[c]	2	Cast steel[d]
WLM (5)	2 (10)	6	12% Cr & CA-6NM
WYTM (13)	1 (13)	Unknown	Superston 40
WLB (11)	1 (11)	Unknown	12% Cr

[a] One set in Yard known.
[b] Material of installed units (materials of spares uncertain).
[c] Including one bow propeller.
[d] Hub and blades are cast as a single unit.

[44] Interview with CDR Kenneth E. Wagner, USCG, CWO Robert W. Jackson, USCG, and LT Robert W. Gulick, USCG, (G-ENE-4/64), Washington, D.C. 15 March 1978.

[45] DOT, U.S. Coast Guard (G-OP/74), Register of Cutters of the U.S. Coast Guard (CG-197), Washington, D.C., 1 July 1976.

AD-A057 347 ENVIRO CONTROL INC ROCKVILLE MD F/G 5/1

A STUDY OF CRITICAL MATERIALS FOR THE U.S. COAST GUARD.(U)

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The status of spare icebreaker propellers, blades, and hubs is in a state of uncertainty at present [46]. An effort to obtain an inventory of spare propellers from the Ships Inventory Control Point (SICP) indicated that several existing propellers are composed of unknown materials. There are at least 10 stock numbers covering various types of propellers for cutters with icebreaking capabilities. There is currently an effort under way by the SICP to clarify the status of such propellers.

U.S. Coast Guard icebreakers are designated by type in terms of the maximum thickness of clear blue ice that can be broken while running continuously. Table IV-20 presents the six types of icebreakers and their continuous icebreaking capability.

Table IV-20

ICEBREAKER TYPES

(Source: Reference [47])

Type	Continuous Icebreaking Capability
P	Greater than 4 feet
A	Between 3 and 4 feet
B	Between 2 and 3 feet
C	Between 1.5 and 2 feet
D	Between 1 and 1.5 feet
E	Between 0.5 and 1 feet

The Coast Guard's requirements for new icebreakers through the year 1991 are presented in Table IV-21. With the new acquisitions proposed in Table IV-21 and the planned decommissioning of the WESTWIND and the GLACIER in 1985 and of the NORTHWIND in 1986, the icebreaker inventory shown in Table IV-22 would result. However, due to various funding uncertainties, the acquisition dates for new cutters have been adjusted, and thus the inventory shown in Table IV-22 will change. A new cutter plan, superseding the current one, will be issued in the first half of 1978 [48]. Upon the promulgation of the new cutter plan, Tables IV-21 and IV-22 can be updated.

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[46] Interview with CDR H. Fallon, USCG, Ships Inventory Control Point, U.S. Coast Guard, Curtis Bay, Maryland, 3 April 1978.

[47] Department of Transportation, U.S. Coast Guard, Office of Operations, Plans and Programs Staff, *Projected United States Coast Guard Icebreaking and Icebreaker Requirements, 1975-2000*, Washington, D.C., February 1975.

[48] Interview with Mr. Paul Dzmura, U.S. Coast Guard (G-OP), Washington, D.C., 21 March 1978.

Table IV-21

RECOMMENDED ICEBREAKER ACQUISITIONS
(Delivery at Beginning of Fiscal Year Shown,
With 10-Year Service Life of WIND-R Class)
(Source: Reference [47])

Type	1978	1979	1980	1981	1982	1986	1987	1991
B-A[a]						2	1	
B-L[a]		1						
C	1[b]	4	5	4				1

[a]Types B-A and B-L are both Type B icebreakers with the additional designations (A-arctic, L-lakes) referring to endurance levels.

[b]Funded in FY 1976 (to be delivered in October).

Table IV-22

PROJECTED ICEBREAKER INVENTORY (At Beginning of Fiscal Year and With 10-Year Extended Service Life on WIND-R Class)
(Source: Reference [47])

Type	Area of Operation	1978	1979	1980	1981	1986	1987	1991
P	Antarctica-Arctic West	2	3	3	3	2	2	2
A	Arctic East	1½[a]	2	2	2	1	0	0
	Great Lakes		0	0	0	0	0	0
B-A	Arctic East	0	0	0	0	1	2	2
	Arctic West	0	0	0	0	1	1	1
B-L	Great Lakes	0	1	1	1	1	1	1
C	Great Lakes	1	5	5	9	9	9	10
	1st District	0	0	2	2	2	2	2
	3rd District	0	0	2	2	2	2	2
	5th District	0	0	1	1	1	1	1
D	WLB -Great Lakes	5	5	5	5	5	5	5
	WYTM-Great Lakes	4	0	0	0	0	0	0
	WYTM-1st District	2	2	0	0	0	0	0
	WYTM-3rd District	3	3	0	0	0	0	0
	WYTM-5th District	3	3	0	0	0	0	0

[a]Reflects current split deployment of WESTWIND.

The best available information indicates that the Type C icebreakers will be delivered according to the following schedule: one in October 1978, three in 1979, and two in 1980 [49]. The current estimates indicate that the life cycle of the WIND-R class will be extended by 10 to 12 years by the re-engining program. This would mean that the WESTWIND's replacement may join the fleet in 1981. A concept combining arctic endurance and shallow draft to permit operations in the Great Lakes is currently being considered to replace the WESTWIND. It is designated Type BAL and would have a split deployment similar to that of the WESTWIND. The NORTHWIND replacement (Type B-A) would then be deployed about two years later in 1983. Replacement for the GLACIER (Type P) is slated for after 1990.

At present, there is no standard level of spares of any large line item equipments such as propellers that are required for new ships. The SICP at Curtis Bay, Maryland, is making a tentative analysis of the optimum time frame for purchase of such large items as propellers. Life-cycle costing is not presently utilized in the funding of new units; rather, such items are procured on an as-required basis.

5. *Alternatives*

Several potential solutions are availabile to help alleviate a potential problem in procuring propellers for icebreakers. Stockpiling, alternative alloys, and salvage and repair of damaged propellers are all possible.

Stockpiling of propellers of Superston 40 [42) has resulted in some surface cracks. Subsequent heat treatment of the cracked blades appears to have solved the problem. However, blades made of other alloys have been stored with no problems. Life-cycle costing of stockpiling policies would aid in the development of a suitable level inventory for each operating unit. The work that is now being done by the SICP may provide some of the answers. The materials required to actually cast the blades, which could become limiting factors, are currently being stockpiled nationally. They would be available via the Defense Production System administered by the Department of Commerce.

CA-6NM could substitute for the Superston-40 blades currently in use without an extensive research and development commitment by the Coast Guard. CA-6NM is being used in place of the 12-percent chromium used in the past. The new material is stronger, is less susceptible to corrosion, has better weldability, is easier to pour, and has better impact-resistance than the conventional stainless alloy. The CA-6NM was first used for large-valve bodies and hydro-turbine installations. The new material is being utilized for its superior properties rather than for any materials shortage considerations. As shown in Table IV-18, CA-6NM uses basically the same elements as do the other materials shown in the table.

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[49] Interview with CDR William P. Hewel, USCG (G-OOO-2/74), Washington, D.C., 21 March 1978.

The present practice is to replace all blades on polar icebreakers rather than only the broken blades. Hubs are not generally replaced due to broken blades. There is some possibility of salvage of the remaining blades. Repairs are being made on blades at present, and the extent of such repairs is carefully controlled in applicable specifications (e.g., MIL-STD-278). The Aerospace Corporation of El Segundo, California, performed a study of the GLACIER's propellers and their component materials [50]. It yielded a heat-treating process to effect repair, an evaluation of the failed material, and provided an analysis of repaired propeller blades.

6. *Conclusions*

- Propellers for icebreakers are not easily procured. There are a limited number of suppliers due to the reluctance of vendors to deal with exacting Coast Guard Military Specifications, uneconomical order sizes, difficulties in casting and machining, and new environmental requirements on foundries.

- Long lead times for procurements have been experienced, although no actual shortages have occurred.

- The availability of the component materials for the propeller castings will not be a problem for the Coast Guard.

- There are sufficient spare propellers existing for immediate expected needs. The Ships Inventory Control Point (SICP) is investigating lead time, inventories, and stock identification.

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[50] Aerospace Corporation, *Repair and Heat Treatment of Mn-Ni-Al Bronze Blades and Evaluation and Quality Assurance Requirements of Shaft Steels on USCG "GLACIER"*, Aerospace Corporation, El Segundo, California, July 7, 1977.

E. *PAPER*

At present our national economy requires enormous amounts of paper to fulfill a variety of uses. Over 32 million tons of paper were consumed in 1976; this is an increase of 109% over the 15.3 million tons that were consumed in 1950 [51]. Paper is used for various types of communications media, building products, packaging material, feedstocks for specialty products such as formica, and for numerous disposable and decorative products. The uses of paper are so widespread and commonplace that they often go unnoticed.

1. *Past Shortage Experience*

There is usually little concern given to the continued availability of paper since it is produced from timber, which is a renewable resource. However, conditions during 1973-1974 indicated that the continuing availability of paper, pulpwood, wood chips, wood pulp, and paperboard could no longer be taken for granted. Over a period of time, a number of complicated factors, economic, social, and political, combined to effect spot shortages of these materials. The shortages that occurred during this period will be examined in terms of long-term, intermediate, and short-term causes, in order to recognize and utilize advance indicators of future shortages [52].

a. *Long-Term Causes of Shortages*

A number of basic causes developed in the 1950's. There was a net reduction in the acreage of forest land that was available for commercial logging operations. Table IV-23 shows the area of commercial timberlands in the United States from 1952 to 1970.

While the total area remained constant, the area available for logging decreased. Public forests, which comprise over 25 percent of commercial timberland, were increasingly set aside for recreational or other uses. A substantial portion of private lands was not generally made available for logging operations resulting in a net decrease of these lands available to the forest products industry. Since the passage of the Wilderness Act (P.L. 88-557) in 1964, 14.7 million acres of Federal land have been designated for preservation [53]. The current bills before Congress, if all became laws, would set aside an additional 148.9 million acres.

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[51] Lowe, K. E., Paper industry posts good recovery from 1975 levels, despite some poor pricing, *Pulp and Paper 51*(7):21-30, June 1977.

[52] National Commission on Supplies and Shortages, *The Commodity Shortages of 1973-1974: Case Studies*, U.S. Government Printing Office, Washington, D.C., August 1976.

[53] Wilderness bills threaten supply, *Pulp and Paper 52*(1):69, January 1978.

Table IV-23

AREA (thousand acres) OF COMMERCIAL TIMBERLAND, BY REGION: 1952, 1962, and 1970
(Source: Reference [54])

Region	1952	1962	1970	% Change 1952-1970
North[a]	170,198	175,089	177,901	+4.53
South[b]	192,082	199,905	192,542	+0.24
West[c]	132,696	133,141	129,254	-2.59
All regions	494,978	508,137	499,697	+0.95

[a]New England, Middle Atlantic, Lake States, and Central regions.
[b]South Atlantic and Gulf regions.
[c]Pacific Coast and Rocky Mountain regions.

Table IV-24 indicates the productivity increases resulting from improved timber management practices. It shows that land held by the forest industry showed greater productivity per acre over the land held in the public and the farm and miscellaneous categories. This is a result of tree farming, application of genetic principles, reforestation, and fire control practices by the forest industry.

Table IV-24

PRODUCTIVITY IMPROVEMENT AS MEASURED IN ANNUAL GROWTH PER ACRE[a]
(Source: Reference [54])

Ownership	1952	1962	1970	% Improvement 1952-1970
Public	23.9	28.1	31.8	24.8
Farm & Miscellaneous	27.0	30.5	36.3	25.6
Forest Industry	42.8	49.6	51.7	17.2
North	33.2	39.5	40.7	18.4
South	44.6	51.8	53.1	16.0
West	48.6	55.3	61.9	21.5

[a]Annual Growth/Acre = $\frac{\text{annual growth in thousand cubic feet}}{\text{ownership in thousand acres}}$

[54] U.S. Department of Agriculture, Forest Service, *The Outlook for Timber in the United States*, Forest Resource Report No. 20, U.S. Government Printing Office, Washington, D.C., July 1974.

The net result of the two trends has been an increase in timber production from 10,745 million cubic feet in 1952 to 12,154 million cubic feet in 1970.

Exceptionally high growth patterns in the 1960's eventually exhausted the pulp and paper industry's ability to attract additional capital necessary to sustain that expansion during the early 1970's. During the 1960's, major corporations in the pulp and paper industry followed development strategies that first increased their corporate presence from regional to national bases and then began vertical expansions. This meant that those industries that were engaged primarily in the manufacture of lumber from timber now built or acquired pulp and paper mills to utilize their sawmill fiber residues. Other firms that had been formerly engaged in pulp and paper production then integrated downward into the ownership of large acreages of forest land. Capital became scarce in the 1970's.

The pricing structure of paper products discouraged conservation of paper and paper products, since low prices persisted despite increases in product demand. This was caused largely by the pulp and paper industry's capital-intensive nature which required sustained market shares to return fixed costs. New mills that were needed for the expansion of productive capacity could only be built by committing substantial funds. The initial period until recovery of such investments is quite long—three or four years from commitment to initial production. This requires debt financing and means that a substantial portion of long-term costs will be fixed for charges of interest and capital return. Table IV-25 shows the historically increasing ratio of long-term debt to net worth from 19.7% in 1954 to 43.4% in 1971.

Table IV-25

DEBT/CAPITAL RATIO FOR PAPER & ALLIED PRODUCTS INDUSTRY (in millions of $)
(Source: Reference [52])

Year	Net Worth	Long-Term Debt	% Long-Term Debt / Net Worth	Total Capital	% Long-Term Debt / Total Capital
1954	5,066	996	19.7	6,062	16.4
1955	5,623	1,116	19.8	6,739	16.6
1956	6,168	1,371	22.2	7,539	18.2
1957	6,363	1,621	25.5	7,984	20.3
1958	6,563	1,602	24.4	8,165	19.6
1959	6,617	1,542	24.1	8,209	19.4
1960	6,991	1,833	26.2	8,824	20.8
1961	7,315	1,865	25.5	9,180	20.3
1962	7,771	2,123	27.3	9,894	21.5
1963	7,521	2,221	29.5	9,742	22.8
1964	8,078	2,062	25.5	10,140	20.3
1965	8,262	2,402	29.1	10,664	22.5
1966	8,797	3,140	35.7	11,937	26.3
1967	9,226	3,731	40.4	12,957	28.8
1968	9,550	3,941	41.3	13,491	29.2
1969	10,476	4,228	40.4	14,704	28.8
1970	11,061	4,659	42.1	15,720	29.6
1971	11,148	4,866	43.6	16,014	30.4

The high fixed charges require operation of the mill at close to capacity. Table IV-26 shows that from 1955 to 1973, the lowest operating rate was 86.5 percent and the mean was 93 percent. In a buyer's market, sales of products resulting from close to capacity operation can only be achieved by increasing the market share, usually by price cutting and/or cost-enhancing tailoring of products and services. Thus, prices were again kept relatively low and did not reflect the true cost of production, nor did they encourage conservation.

Table IV-26

U.S. PAPER—CAPACITY, PRODUCTION, AND OPERATING RATES, 1955-1974P[a]
(Source: Reference [52])

Year	Year End Capacity (thous. tons)	Percent Increase	Production (thous. tons)	Percent Increase	Operating Rate[b] on Average Annual Capacity
1955	13,757		12,905		
1956	14,477	5.2	13,990	8.4	99.1%
1957	15,185	4.9	13,581	(-3.0)	91.6
1958	16,030	5.6	13,497	(-0.6)	86.5
1959	16,825	5.0	15,071	11.7	91.7
1960	17,410	3.5	15,399	2.2	90.0
1961	18,134	4.2	15,833	2.8	89.1
1962	18,531	2.2	16,537	4.4	90.2
1963	19,149	3.1	17,300	4.6	91.8
1964	19,662	2.7	18,152	4.9	93.5
1965	20,499	4.3	19,187	5.7	95.5
1966	22,423	9.4	20,653	7.6	96.2
1967	23,167	3.3	20,944	1.4	91.9
1968	24,174	4.3	22,398	6.9	94.6
1969	25,257	4.5	23,595	5.3	95.5
1970	25,806	2.2	23,625	0.1	92.5
1971	26,270	1.8	23,811	0.8	91.4
1972	27,156	3.4	25,435	6.8	95.2
1973	28,058	3.3	26,536	4.3	96.1
1974P	28,572	1.8	26,671	0.5	94.2

[a] P = Preliminary.

[b] Operating Rate based on Production divided by Average Annual Capacity.

The industry lacked the flexibility necessary to respond to short-term variations in product demand, due to the inflexibility of large mills designed for efficient production at near capacity. This shows that an oversupply of output can result as demand falls off when the economy cools as it did in the 1969 recession.

b. Intermediate Causes of Shortages

Several factors can be identified from the intermediate period of 1969 to 1972. During this period, a new managerial focus emerged, in which the woodlands and manufacturing orientation of the 1950's and early 1960's was replaced by *financial and marketing emphasis.* Industry profits were eroded as a result of the intensified price competition that was necessary to cope with the overcapacity that had developed in the late 1960's. Lead times between decisions to harvest new timber supplies and their execution increased to as much as one year. These delays were caused by additional time required to build logging roads and to establish other infrastructure required to harvest and move timber from the forest to the pulp mills. The installation of pollution control equipment became a major drain on capital funds during this period. The pulp and paper capacity of the United States was reduced by almost four percent through mill closings. In several cases, the costs of installing pollution abatement equipment exceeded the mill's value.

Wage and price controls encouraged manufacturing techniques that were wasteful of fiber. Some industry spokesmen asserted that price controls were damaging because they were imposed during a period of low prices and high costs [52]. The artificialities of controlled prices distorted the usual optimal allocation of materials mix for maximum profit. As a result, fixed prices for products resulted in wasted materials which could not be used optimally. Pulpwood and wood chips were not included in the control system, since they are classified as agricultural commodities; however, paper and paperboard products were included.

Another contributing factor was the development of a shortage mentality among customers. This caused a surge of orders at a time when the industry's pulpwood inventories were unusually low. The results were spot unavailabilities of some products.

c. Short-Term Causes of Shortages

Several short-run causes of pulp and paper shortages, which developed during 1973 and 1974, were noted in various areas of the country. In the East the supply was constrained by labor scarcities, transportation bottlenecks, bad weather in both the United States and Canada, and price competition from overseas demands for available North American timber resources. In the West, the cutback of lumber production due to a decline in housing starts and other demand factors decreased the availability of wood chips which limited wood pulp and paper production. All regions experienced shortages of organic chemicals, binders, resins, and other supplies used in pulpmaking and papermaking. Demands were also artificially sustained at the high levels of the business recovery of 1972 by the developing shortage mentality.

While wood pulp and total paper and paperboard production increased during 1973, the industry was not able to keep up with the overall growth of product demand; in this respect, the 1973 shortages were real. The shortage mentality intensified a series of marginal supply interruptions and inventories were unnecessarily built up in advance of need. With the exception of the publishing and food-packaging industries, the growth trends of paper and paperboard consumption were sustained throughout the 1973-1974 period.

2. *Potential Developments*

There have been relatively few new firms entering the pulp and paper industry over the past 10 years, due to the large capital investments required. At present, most expansion is being done by the larger, more profitable firms. Table IV-27 shows the distribution of capacity to produce printing and writing papers among the top 12 U.S. firms. The 1976 summary of pulp, paper, and board shows a 14-percent growth over the 1975 figures [52].

Table IV-27

ESTIMATED CAPACITY OF MAJOR U.S. PAPER COMPANIES FOR PRINTING AND WRITING PAPERS
(Source: Reference [55])

	Paper Companies	Annual Capacity (1000s tons)	Capacity Share (%)
1.	International Paper Co.	691	9.4
2.	Boise Cascade Corp.	639	8.7
3.	Champion International	602	8.2
4.	Hammermill Paper Co.	525	7.1
5.	Great Northern Nekoosa Corp.	511	6.9
6.	Georgia-Pacific Corp.	508	6.9
7.	Weyerhaeuser Co.	485	6.6
8.	Scott Paper Co.	443	6.0
9.	Mead Corp.	404	5.5
10.	Union Camp. Corp.	303	4.1
11.	Brown Co.	266	3.6
12.	Bergstrom Paper Co.	245	3.3

Note: U.S. capacity (1976): 7.361 million tons
Capacity shares of five top companies: 40.3%
Capacity shares of 12 top companies: 76.3%

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[55] Exclusive review of marketing trends for major grades of paper, paperboard, board, *Pulp and Paper 51*(7):31-40, June 1977.

Figure IV-18 illustrates the recovery of production of pulp and paper products since the 1974-1975 period of low production that followed the 1973-1974 period of unusually high demand.

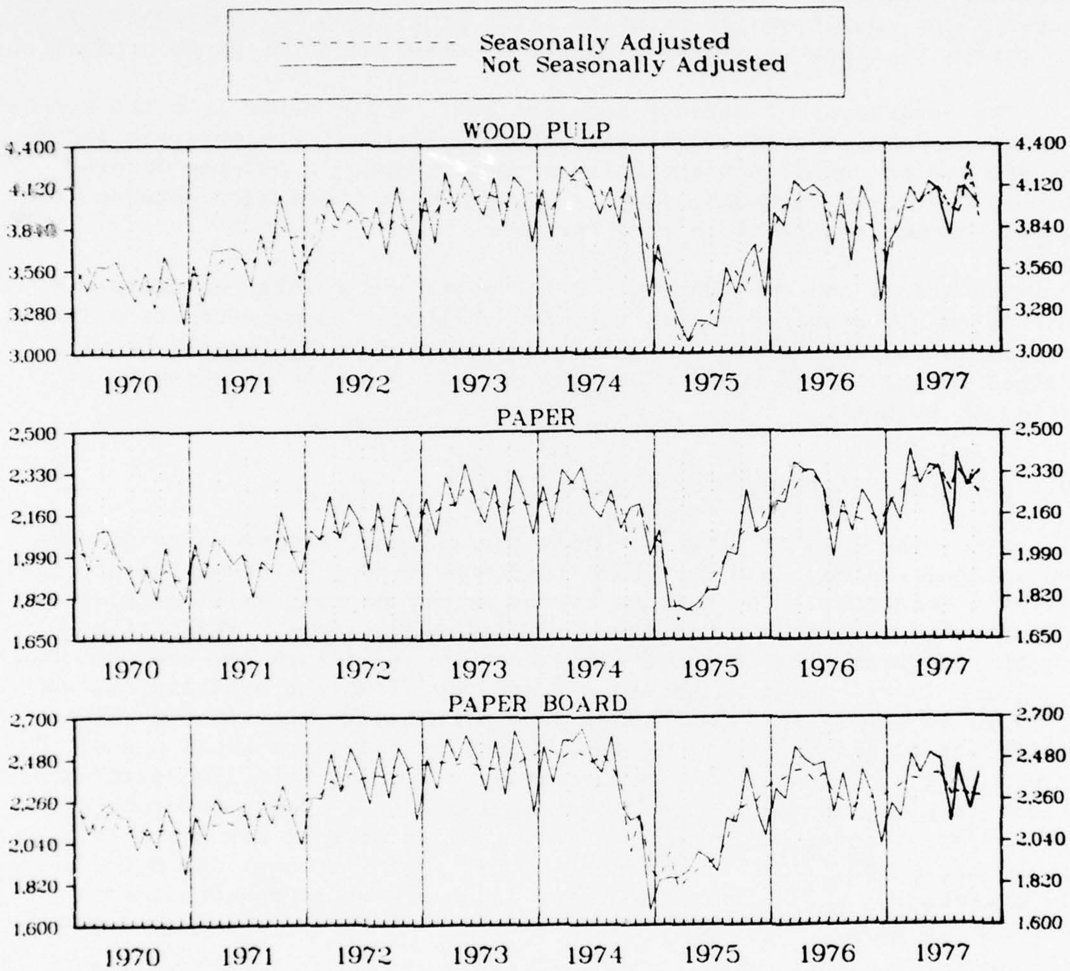

Figure IV-18

PRODUCTION OF PULP, PAPER AND BOARD, 1970-1977
(Thousands of Short Tons)
(Source: Reference [56])

[56] U.S. Department of Commerce, Bureau of the Census, *Current Industrial Reports: Pulp, Paper, and Board, November 1977*, M26A(77)-11, Issued January 1978.

3. *Current Status*

At present, the paper industry is supplying products at less than full capacity in all product forms but the coated printing papers [57]. The large increase in trade journals and the printed overflow of advertising from the television industry are keeping the demand for coated printing paper high. While coated printing paper production is running at close to capacity, there is excess capacity in other areas of paper production.

The Department of Defense acquires most of its paper from the General Services Administration (GSA) with two exceptions. Photographic and map papers are procured from the Defense Supply Agency's Defense General Supply Center in Richmond, Virginia. The Coast Guard also obtains its paper through requisitions from the GSA.

The actual consumption figures for paper and related products are maintained by computer within the GSA. Although such information is not readily available since it requires collating data by Federal Stock Number for all Coast Guard procuring units, it can be obtained by an official request.

4. *Potential Shortage Scenarios*

Since the uses of paper are quite varied and in many cases provide convenience rather than necessity functions, shortage scenarios are difficult to construct. The private sector of our economy still considers paper virtually a free good that is readily available. The public's demand for packaging is constrained only by its demand for the products enclosed in the paper packaging. Therefore, if paper actually did become limited in supply and some grades were potentially unavailable, it is difficult to imagine what, if any, necessary functions would cease. Cutbacks in the conveniences provided by paper could cause immediate reductions in paper demands. Such nonessential uses as paper decorations, oversize and other packaging at the retail level that are designed to help curb shoplifting, free trade journal subscriptions, and other forms of advertising utilizing inexpensive paper presently require large amounts of paper.

As a result of the experiences of the 1974 recession, there has been little increase in paper manufacturing capacity. Hesitancy over capital investments stems, in part, from uncertainty about pollution abatement regulatory impacts. The special study done for the National Commission on Supplies and Shortages [52] comes to the following pessimistic conclusion:

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[57] Interview with Mr. Donald Butts, Commodity Analyst, U.S. Department of Commerce, Office of Business Research and Analysis, Washington, D.C., 7 March 1978.

"Domestic conditions for the emergence of spot shortages therefore exist. If an international recovery of economic activity were to occur in a fashion paralleling 1972-1973, there would be strong reason to predict a return to scarcity. The new scarcity would not, however, be identical to that of 1973 and 1974—so long as it were determined to let price changes in the marketplace help bring adjustment of product supply to demand. Sharp price fluctuations would, of course, rapidly put to rest the belief that much paper and paperboard is essentially a free good.

"Lacking the 1971-1974 type of price regulation, and aided by a more accurate perception of the economic value of paper and paper products, major causes of 'apparent' shortage would evaporate. However, we point out that temporary 'real' spot shortages may occur even before the current cyclic upswing runs its course. Bottlenecks still exist to limit rapid demand-supply adjustment in the marketplace. Where inexpensive substitutes are lacking, domestic demand for paper and paperboard products seems likely to grow with further increases in real national income. As this occurs, there may be considerable pressure on available supplies.

"Our short-run prognostication could, of course, be thrown off by re-emergence of a world boom similar to that which occurred in 1972-1973. Currently, this appears unlikely. If storms and floods of the 1972-1973 type were to recur, they would clearly lead to spot shortage conditions of greater intensity than we project. However, we believe bad weather would tend to increase 'high grading' activities by pulp and paper manufacturers--that is, a bad winter will in future move production in the direction of products with the greatest utilitarian value. This appears to be an acceptable end result." [52]

The study is even more pessimistic about long-term shortages which will eventually impact on the structure of the pulp and paper industry.

5. *Consumption Projections*

Consumption of paper and board increased from 7.7 million tons in 1920 to 64.3 million tons in 1972. This increased at an average rate of growth of 4.8 percent from 1920 to 1940 and 4.1 percent thereafter [58]. Paper consumption has a close statistical relationship to per capita disposable personal income. This can be used as a predictive value for forecasting

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[58] U.S. Department of Agriculture, Forest Service, *The Outlook for Timber in the United States,* Forest Resource Report No. 20, U.S. Government Printing Office, Washington, D.C., October 1973.

paper consumption. Figure IV-19 shows the historical relationship. Historical data and projections to the year 2000 for consumption of paper are shown in Table IV-28. Figure IV-20 provides a graphical representation of the data in Table IV-28 including the low, medium, and high projection levels.

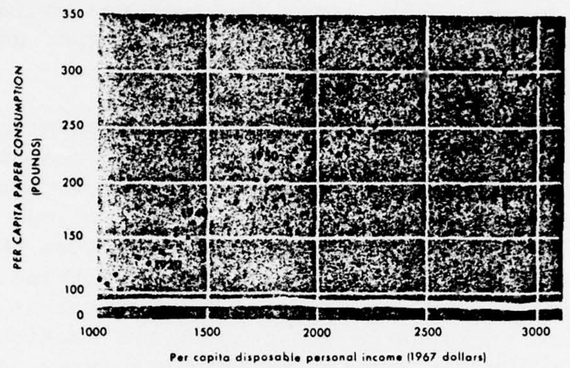

Figure IV-19

RELATIONSHIP BETWEEN PER CAPITA PAPER CONSUMPTION AND PER CAPITA DISPOSABLE PERSONAL INCOME, 1929-1970
(Source: Reference [58])

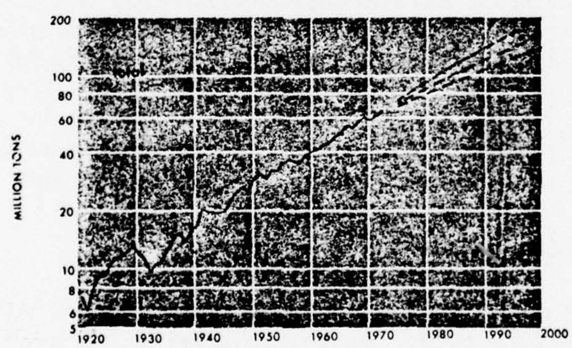

Figure IV-20

PAPER AND BOARD CONSUMPTION, 1920-1971, WITH PROJECTIONS TO 2000
(Source: Reference [58])

Table IV-28

PAPER AND BOARD CONSUMPTION, SELECTED YEARS 1920-1972, WITH PROJECTIONS OF DEMAND (1970 RELATIVE PRICES) TO 2000[1]

(Source: Reference [58])

Year	Total paper and and board		Paper		Paperboard [2]		Building board	
	Total	Annual rate of change [3]	Total	Annual rate of change [3]	Total	Annual rate of change [3]	Total	Annual rate of change [3]
	Million tons	*Percent*	*Million tons*	*Percent*	*Million tons*	*Percent*	*Million tons*	*Percent*
1920	7.7	-------	5.4	-------	2.3	-------	-------	-------
1925	10.4	6.2	7.1	5.6	3.2	6.8	0.1	-------
1930	12.3	3.4	8.4	3.4	3.8	3.5	.1	-------
1935	12.8	.8	8.2	-.5	4.5	3.4	.1	-------
1940	16.8	5.6	10.6	5.3	6.0	5.9	.2	14.9
1945	19.8	3.3	11.0	.7	7.9	5.7	.9	35.0
1950	29.1	8.0	16.8	8.8	11.0	6.8	1.2	5.9
1955	35.0	3.8	19.4	2.9	13.9	4.8	1.7	7.2
1960	39.3	2.3	22.1	2.6	15.4	2.1	1.9	2.2
1965	49.2	4.6	26.8	3.9	19.9	5.3	2.6	6.5
1966	52.8	7.3	28.9	7.8	21.5	8.0	2.4	-7.7
1967	52.0	-1.5	28.8	-.3	20.8	-3.3	2.4	-------
1968	55.8	7.3	30.2	4.9	22.8	9.6	2.8	16.7
1969	59.0	5.7	31.8	5.3	24.2	6.1	3.0	7.1
1970 [4]	58.1	-1.5	31.7	-.3	23.5	-2.9	2.8	-6.7
1971 [4]	59.7	2.8	32.4	2.2	23.9	1.7	3.4	21.4
1972 [4]	64.3	7.7	34.1	5.2	26.4	10.5	3.8	11.8
Low projections								
1980	78.2	2.9	41.0	2.5	33.2	3.3	4.0	2.8
1990	102.5	2.7	52.2	2.4	45.1	3.1	5.2	2.6
2000	130.4	2.4	64.4	2.1	59.4	2.8	6.6	2.4
Medium projections								
1980	83.1	3.5	43.4	3.1	35.5	4.0	4.2	3.5
1990	116.1	3.4	59.2	3.2	51.1	3.7	5.8	3.3
2000	156.5	3.0	78.0	2.8	70.7	3.3	7.9	3.1
High projections								
1980	89.0	4.2	46.5	3.8	38.0	4.7	4.5	4.2
1990	132.7	4.1	67.6	3.8	58.4	4.4	6.7	4.0
2000	190.2	3.7	94.1	3.4	86.4	4.0	9.7	3.8

[1] Projections based on alternative assumptions about growth in population and economic activity as specified in the introductory section of this chapter.
[2] Includes wet machine board.
[3] The average annual rate of change for 5-year periods ending in the specified years except for the years 1965-72 when annual changes are shown.
[4] Preliminary.

6. *Technological Changes*

Changes being made in today's pulp and paper mills are either for increased efficiency and therefore production, or to allow the mill to comply with air, water, and solid waste pollution standards. Advancements are also being made in the growing and harvesting of timber for pulp production.

The thermomechanical pulping (TMP) process allows the production of a pulp that is stronger than mechanical pulp and cheaper than chemical pulp. It also has less strength than the chemical pulps but sufficient strength to move into some processes that once required chemical pulp, such as

newsprint. TMP is also being used in the plybond process to reduce the amount of bleached chemical pulp required. The finished product consists of three layers of paper: the outer layers are formed from bleached chemical pulp and the inner layer is formed of unbleached TMP. This results in a less expensive product capable of performing as well as the more expensive material [57,59].

Methods are being developed to increase mill efficiency, such as: improvements in papermaking and winding machinery, increased use of computers to monitor processing equipment and to direct plant operations, and improved heat-recovery systems to conserve fuel. Measures allowing compliance with air and water standards involve the installation of treatment systems designed to remove greater amounts of pollutants. These systems include: air scrubbers to remove SO_x; improved treatment processes for wastewater to reduce its organic content and thus the chemical oxygen demand; substitution of diaphragm cells for mercury cells in the production of caustic and chlorine to eliminate mercury from effluents; development of polyamides to remove color from mill effluents; recovery furnaces (with multicyclone dust collectors and scrubbers) to burn digestor wastes; and installation of black liquor oxidation systems to reduce odors.

A development designed to improve timber harvesting in regions lacking infrastructures will be introduced into Brazil in 1978 [60]. It is a floating plant built by a Japanese firm in two units and towed to a prepared site on a tributary of the Amazon. The plant is designed to produce 750 tons of cellulose per day and to derive the required energy from local organic fuels such as wood and grass. It has been estimated that two years' time and 20 percent of construction costs were saved by building the facility in Japan and moving it to the site instead of building it on-site.

Improved forestry-management techniques have greatly improved yields of timber per acre in the past and continue to do so. An approach is being developed by the Institute of Paper Chemistry with considerable involvement by private industry, particularly Weyerhaeuser, and universities. This method involves tissue culture replication of trees with desirable characteristics. The process also offers a method of evaluating hybrids by allowing production of identical replicas instead of the normal one specimen yielded by a genetic cross. There is also the possibility of creating hybrids by protoplast fusion of species that would not normally cross with each other [61]. Other methods of improved forestry management include: fire control, tree farming, reforestation, improved herbicides

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[59] Interview with Mr. James Mock, Plant Engineer, Continental Forest Industries, Augusta, Georgia, 9 March 1978.

[60] Rohter, L., Factory built on a barge floats to site in Brazil, *The Washington Post,* 8 March 1978.

[61] Hanson, J. P., Studies indicate test-tube trees could be future pulpwood source, *Pulp and Paper 51*(6):60-63, June 1977.

to limit competition by other plants for nutrients and space required by seedlings, and improved chemical and biological controls of insect pests of timber.

7. *Impact on the Coast Guard*

At present virtually all of the paper products utilized by the Coast Guard are procured from the GSA, which is the central ordering facility for the entire Federal Government and its component agencies [62]. Following procurement, GSA provides storage facilities across the country for stocked items, including paper and related products. Distribution is then made from GSA stocks to the various Government agencies on the basis of requisitions. Both the Department of Transportation and the U.S. Coast Guard requisition blank paper and paper products from GSA. Printed forms are provided via the Government Printing Office (GPO) using GSA-procured paper in most cases. The printing needs peculiar to the Coast Guard, such as regulations, reports, and other nonstandard items, are handled through the Department of Transportation Printing Service.

GSA inventories are turned over several times per year, and a large excess stock is not maintained. The GPO inventories are also maintained in GSA warehouses. The expenditures required for actual stockpiling of paper and printed forms would outweigh the benefits that could be derived therefrom. Thus, quantities on hand are maintained to meet current anticipated demands. When accelerated ordering occurs in excess of actual agency requirements (e.g., by hoarding), stocks can become depleted. This can occur in any stocked paper item, but is more pronounced in specialty items maintained in small quantities, i.e., certain printed forms. Conversations with several sources indicated that the shortages that occurred in 1973 and 1974 were more imaginary than real [57,59,62]. It was the shortage mentality that created any problems that did occur. These could have been prevented by proper communication of the real situation to the supply staff and by ordering on the basis of actual need rather than future imagined needs.

Although paper is one of the most widely used commodities in present-day society, it is also one of the most abused. The Coast Guard could function during a period of paper shortages, although operations might be somewhat curtailed. Since paper comes from a renewable resource, a complete lack of paper is very difficult to imagine.

Carrying on normal operations during a period of sharply reduced paper supplies would cause several changes in what is now standard procedure in many offices. Routing one copy of a document rather than xeroxing one for each person, replacement of written communications with oral ones, and producing only essential documents in print are some examples of measures that would aid in the conservation of paper. The proliferation of xerox

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[62] Interview with Mr. Hantman, Director of Paper Products and Office Supplies Division, General Services Administration, Brooklyn, N.Y., 10 April 1978.

and other dry-process copiers have contributed to the growth in paper consumption. Should restrictions in the supply of paper and related products occur, each office would have to evaluate its missions and assess the methods used to accomplish them. Many of the uses of paper have evolved during a period when paper was virtually a free good. As that situation changes, cutbacks in nonessential paper utilization by the Coast Guard, as well as by other Government agencies, will be required.

8. Alternatives to Paper

There are several possible alternatives that might prevent an actual shortage of paper. The most obvious one is to let prices rise to a point where wasteful, one-way use of paper products is discouraged. This could also be accomplished via solid-waste-disposal taxes on all paper and flexible packaging, as proposed by the Resource Conservation Committee established by the Resource Recovery and Conservation Act of 1976.

Recycling is another method of extending existing fiber supplies. In 1976 wastepaper provided 21.7 percent of the raw fibrous material required to produce 60.9 million tons of paper and board in the United States [63]. There is a vast quantity of additional paper contributing to the solid waste problem that could be recycled. Table IV-29 shows that the U.S. consumption of wastepaper has actually declined, when viewed as a percentage of total paper produced. In 1950, 28 percent of 29 million tons consumed was recycled; and in 1975, only 21 percent of the 56 million tons was recycled.

Table IV-29

U.S. CONSUMPTION OF PAPER AND ITS RAW MATERIALS (million tons)
(Source: Reference [64])

Year	Total Paper[a]	Pulp[b]	Wastepaper[b]	Other[b]	(3) as % of (1)
	(1)	(2)	(3)	(4)	(5)
1950	29.0	16.5	8.0	1.4	28
1955	34.7	21.5	9.0	1.3	26
1960	39.1	25.7	9.0	1.0	23
1965	49.1	34.0	10.2	0.9	21
1966	52.7	36.9	10.6	1.0	20
1967	51.9	37.0	9.9	0.8	19
1968	55.7	41.3	10.2	0.9	18
1969	58.9	43.7	12.0[c]	0.9	20
1970	57.9	43.2	11.8	0.8	20
1971	59.6	44.2	12.1	0.9	20
1972	64.4	47.3	12.9	0.9	20
1973	66.7	48.8	14.1	0.8	21
1974	65.5	48.3	14.0	0.8	21
1975	56.0	42.4	11.7	0.6	21

[a]Apparent. [b]Actual (Other refers to rags).
[c]Excludes for use in molded products, after 1969.

[63] Evans, J. C. W., Wastepaper: Outlook is for steady growth in U.S.

However, when the U.S. percentages of recycled paper are compared with world data in Table IV-30, it is clear that we rank in the lower third of the nations. Of the 10 leading industrial nations surveyed, only three have lower rates of utilization of recycled paper. Those countries--like Japan, Germany, and the Netherlands--that depend on wood pulp imports consume relatively more recycled wastepaper. Obviously, there is opportunity for improvement in the U.S. utilization of wastepaper, via recycling.

Table IV-30

1975 CONSUMPTION OF PAPER AND PAPERBOARD AND OF PULP IN 10 INDUSTRIAL COUNTRIES
(Source: Reference [64])

Country	Apparent Consumption (million tons)		Wastepaper Recovery Rate[a] (percent)
	Paper and Paperboard	Pulp	
United States	67.1	50.0	22.1
Canada	3.8	14.0	20.4
Japan	15.9	12.3	39.4
Fed. Rep. Germany	8.4	3.9	30.0
France	5.7	3.5	29.6
United Kingdom	7.6	3.2	27.8
The Netherlands	2.0	1.0	42.0
Finland	0.8	5.9	19.5
Sweden	1.7	5.9	24.0
Norway	0.5	1.8	18.4

[a]Recovery Rate = amount of paper collected as percent of total paper and board consumed.

Improved forestry-management techniques will continue to produce greater yields per acre, although the increases are no longer as significant as they were in the 1950's.

Stockpiling of processed wood pulp by the Federal Preparedness Agency is a possible alternative, but its equitable administration would likely prove quite difficult. The assessment of the relative importance of the various uses of paper by different agencies and the assignment of priorities for using the stockpiled pulp would be extremely complicated tasks.

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utilization, strong advances in exports, *Pulp and Paper 51*(7):144, 30 June 1977.

[64] National Commission on Supplies and Shortages, *Additional Background Studies,* U.S. Government Printing Office, Washington, D.C., December 1976.

Pulp would require storage under specialized conditions, and since the quantity of pulp required to provide paper for any length of time would be huge, the cost of such storage would be extremely high.

Paper also requires protection during storage to prevent damage resulting from excess moisture, mold and mildew, and insect pests. Therefore, the maintenance of a large stockpile of either processed pulp or paper itself would be quite costly. Proper management of resources, increased recycling, and elimination of wasteful practices could be managed more easily. Stockpiling by individual agencies, or hoarding, was one of the contributing factors to the problems in 1973-1974 and should also be discouraged.

Procurement of essential materials can be obtained through the U.S. Department of Commerce's Defense Priorities System and the Defense Materials System. Such materials must be required to promote national defense, meet exigencies of war, or support other programs designated by law and a Presidential finding as being essential to national security and to maximize domestic energy supplies.

Substitutes for paper as an information transfer/storage medium are not economically feasible within the present pricing structure. A rise in price levels for paper where substitution by synthetics or alternate systems would become cost-effective would eliminate many nonessential uses of paper. This would allow sufficient fiber for more essential uses of paper and board. The lessened demand would then allow the price to decline and would preclude the use of substitutes.

9. *Conclusions*

- Paper is a critical material for the Coast Guard. Paper forms were in short supply during the national paper shortage of 1973-1974.

- There are no practical, economic substitutes for paper.

- Stockpiling of paper or paper forms was a contributing factor in the 1973-1974 shortages and should be discouraged. Timely, accurate ordering of paper products to fill actual demands and the recycling of wastepaper will assist in dealing with potential problems in availability.

F. *FERROCEMENT AND PRESTRESSED CONCRETE*

As the price of steel and other boat-building materials rises and as offshore structures increase in size, other materials will be sought for the construction of ships, boats, and floating platforms. Two alternatives are ferrocement and prestressed concrete. Both of these materials are relatively free of corrosion in seawater, less expensive than steel, wood and other materials, easily repaired without drydocking or special equipment, and have comparable performance characteristics.

1. *Nature of Technological Development*

Ferrocement and prestressed concrete both begin with the same basic materials: cement, sand, and water. The major difference is in the method of utilizing the reinforcing material. The strength of ferrocement is provided by layers of wire mesh which are impregnated with mortar. The resulting panel is usually one-half to two inches thick, with less than an inch of mortar covering the outermost layer of mesh. Reinforced concrete, on the other hand, uses large-diameter steel rods or steel cables under tension. These structures are relatively large and have one to several inches of concrete covering the outermost reinforcing member. Ferrocement uses a form but does not require a mold to hold the mortar to the reinforcing medium, as does prestressed concrete.

The two materials, while made from essentially the same components, have quite different end uses. Ferrocement is used primarily for small boats and other structures of moderate to small size. Prestressed concrete lends itself well to massive structures subjected to severe stresses, such as the North Sea oil storage and production platforms.

2. *Historical Development*

Both materials were derived from Joseph-Louis Lambot's wire-reinforced cement boat built in 1848 [65]. Although the concept was essentially ferrocement, the technology of the period could not produce the wire mesh required. The concept was modified, and reinforced concrete was developed. Ferrocement was forgotten until Pier Luigi Nervi built the 165-ton motor sailer *Irene* after the Second World War. At the time of construction, it cost 40 percent less than a comparable wood hull and weighed 5 percent less.

Heavy ship losses due to submarine attacks and the shortages of steel plate led to the use of reinforced concrete as a shipbuilding material during both World Wars. However, the surplus of steel which became available after each war eliminated the need for continuous substitutes for steel hulls.

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[65] National Academy of Sciences, *Ferrocement: Applications in Developing Countries*, National Academy of Sciences, Washington, D.C., February 1973.

The uses of reinforced concrete and ferrocement have been limited in the past, due to their limited tensile strength and low strength-to-weight ratio. The lack of experience with concrete as a shipbuilding material has posed some unusual problems regarding classification [66]. A document from one of the ship classification societies must be obtained before a vessel is deemed insurable. These societies include the British Lloyd's Registry, the French Bureau Veritas, the Norwegian Det norske Veritas, the Spanish Findenavis, and the American Bureau of Shipping. The rules for ship design and construction, as well as the vessels' compliance with the rules in regard to the structural adequacy and seaworthiness, are formulated by the societies. Lloyd's has given insurance discounts due to the fire resistance of ferrocement [67]. Both ferrocement and reinforced concrete vessels have been certified by various shipping bureaus since the Second World War.

3. *Current Status*

The present marine use of ferrocement is limited to yachts, pleasure craft, and fishing vessels. Reinforced concrete is used to construct large floating processing facilities, such as oil production and storage facilities, and has been proposed for use in Ocean Thermal Energy Conversion (OTEC) structures, floating harbor structures, and other platform uses.

Ferrocement has the following advantages as a marine construction material:

- low capital investment for facilities
- low-cost and readily available materials
- low-skill labor requirements
- ease of fabrication and repair
- low maintenance
- fire resistance.

The advantages of reinforced concrete over steel as a marine construction material include:

- lower initial cost
- less maintenance cost since it is relatively corrosion-free in saltwater
- periodic drydocking for inspection, repair, and painting is unnecessary
- superior fire resistance
- resistance to cyclical loading and fatigue.

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[66] Anderson, Arthur R. (ABAM Engineers Incorporated), World's largest prestressed LPG floating vessel: Design, construction, marketing, *Journal of the Prestressed Concrete Institute* 22(1):2-21, January-February 1977.

[67] Brauer, Frank E., Ferrocement for boats and craft, *Naval Engineers Journal*: 93-105, October 1973.

Ferrocement is not widely known as a construction material. The ferrocement industry is still in its infancy, but is showing signs of becoming competitive. Commercial fishing vessels on the west coast of the United States are being replaced with ferrocement boats [67]. Some of the reasons for this are: shorter fabrication time of ferrocement, reuse of fittings from previous boats by ferrocement builders, and lower material costs for ferrocement. The combination of these factors results in a total cost for ferrocement boats that is lower than that for boats made with competitive materials.

One construction technique under development is the use of short lengths of wire in a grout mixture and spraying the combination onto wire forms. This process produces fibrous ferrocement that has a very low rate of crack propagation. Sections can also be bolted together to form a larger structure. However, this process is not presently adapted to the manufacture of boats. It does allow for more efficient and rapid production of structures requiring lower strength and subjected to less stress than vessels. Additional research may provide an adaptation to the marine industry via the development of improved materials.

Fibersteel, Inc., of West Sacramento, California, has been manufacturing 55-ft motor sailers by using a patented process for 13 years [68]. They have the capacity to produce one vessel approximately every two weeks. The company's products have been inspected and approved by the Merchant Marine Technical Office of the Twelfth Coast Guard District. Lloyd's Rules for Ferrocement Construction provided the basic criteria to be met.

Other firms are manufacturing vessels from ferrocement, especially in the northwestern areas of Canada and the United States. Windboats Ltd. of London has built over 400 craft in the past 15 years. The Chinese have been constructing ferrocement boats for approximately 10 years. The U.S. Navy, under Admiral Zumwalt, supervised the building of ferrocement patrol boats in Viet Nam. Present interest is overseas for the most part, especially in New Zealand. However, interest in the United States is steadily, if slowly, increasing. Many boats are still one-shot backyard projects, but established firms show steady sales.

The possibilities of ferrocement vessels were explored by University of Michigan students in the Department of Naval Architecture and Marine Engineering. Table IV-31 compares the scantlings for a 100-ft fishing boat using wood or ferrocement. It should be noted that this boat has not actually been constructed at this time [69].

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[68] Interview with Mr. Louis Watson, Fibersteel, Inc., West Sacramento, California, 4 April 1978.

[69] Canby, D. C. (University of Michigan, Department of Naval Architecture and Marine Engineering), *Ferro-Cement with Particular Reference to Marine Applications*, University Of Michigan, Ann Arbor, Michigan, March 1969.

Table IV-31

SCANTLINGS FOR 100-FT FISHING BOAT
(Source: Reference [69])

	Wood	Ferro-Cement
Hull Thickness	3 in. (Birch & Oak)	1.25 in.
Frame Spacing	22 in.	20 in.
Frame Size		
At Keel	10 3/4 in. x 6 in.	10 in. x 1.9 in.
At Sect. 8	9 in. x 6 in.	8 1/2 in. x 1.25 in.
At Turn of Bilge	8 3/8 in. x 6 in.	6 in. x 1.25 in.
At Deck	5 3/4 in. x 6 in.	6 in. x 1.25 in.
Deck Thickness	3 in. (Pine)	1 in.
Deck Frames	8 in. x 6 in. (Oak)	6 in. x 1 in.
Keel	12 in. x 21 in. (Oak)	12 in. x 21 in.
Keelson	12 in. x 12 in. (Fir)	None
Sister Keelson	(2) 9 1/2 in. x 8 in.	None

Steel enjoys a continuous advantage over reinforced concrete in that it is a more widely used material for most marine applications. There are roughly 1,000 steel platforms in the Gulf of Mexico at present to provide a data base on performance, construction techniques, and other vital characteristics for fixed marine structures. There are highly competitive conditions existing in the steel market, but higher prices and protectionist policies of the Federal Government may make reinforced concrete more competitive [70]. There is currently a lull in the construction of concrete platforms for the North Sea that is expected to last about two years [71]. At the end of that period, a shortage is expected to cause price increases in steel and a resultant increase in the use of concrete.

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[70] Offshore construction report, *Ocean Industry 13*(3):35-39, March 1978.

[71] Cummings, George, Learning curve for concrete platforms not yet completed, *Ocean Industry 13*(3):58-60, March 1978.

Norwegian Contractors has completed five concrete platforms in the North Sea area; they were installed from 1973 to 1976 and are currently onstream. All of these five have storage facilities for crude oil, and Ekofisk One, installed in 1973, has the capability to store one million barrels of crude oil. The Frigg TCP-2, installed in 1977, contains facilities to compress and store natural gas [72].

Eight additional platforms are currently being constructed worldwide, with completion dates scheduled during 1977 and 1978 and onstream dates ranging from early 1978 to 1980 [73].

Prestressed concrete is well adaptable to the construction of large floating structures and platforms. In this case bigger is definitely better, because the large size allows proper placement of the reinforcing materials. The American Bureau of Shipping recently removed a major obstacle to the acceptance of prestressed-concrete floating facilities when it agreed to classify a liquefied petroleum gas (LPG) vessel for the Atlantic-Richfield Company. The 65,000-ton vessel is designed to produce LPG from natural gas in the Ardjuna oil field and store it in tanks on board [74]. It will be moored in the Java Sea, via a single-buoy mooring system, 20 miles off the coast of Java. The purpose is to recover the $100,000 per day of gas that comes up from wells with crude oil and is presently flared off as a waste product. The plant will liquefy and store the gas, up to 36,000 tons, for later transfer to refrigerated tankers for transportation. Figure IV-21 provides an artist's conception of the completed plant on station in the Java Sea.

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[72] Advertisement from Norwegian Contractors, Oslo, Norway, *Ocean Industry 13*(2):124, February 1978.

[73] Cashman, Margaret D., Offshore platforms under construction and planned, *Ocean Industry 13*(3):40-50, March 1978.

[74] Anderson, Arthur R., A 65,000-ton prestressed concrete facility for offshore storage of LPG, *Marine Technology 15*(1):14-26, January 1978.

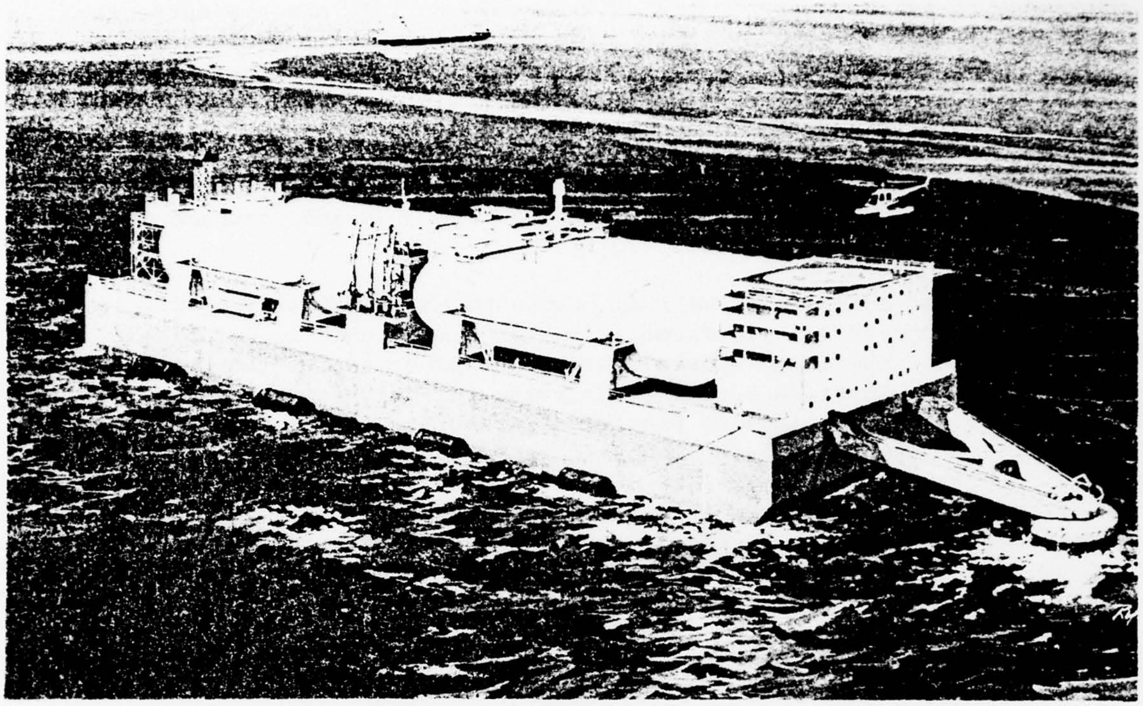

Figure IV-21

LPG FLOATING STORAGE FACILITY FOR ATLANTIC RICHFIELD INDONESIA, INC.
(Source: Reference [74])

4. *Potential Developments*

There are many technological, political, and economic factors that impinge on the use of both ferrocement and reinforced concrete as substitutes for steel. Steel is expected to grow in demand at approximately two percent per year through 1985 [10]. The steel industry spent $740.9 million on environmental projects in 1977 and $489 million in 1976. As these and other costs continue to grow, steel is expected to continue to increase in price. While there is no shortage seen in iron ore, both the metals required for alloying and the iron ore are expected to become more expensive. Many of the alloying elements are derived from ores not located in the United States. Cement, on the other hand, is a local material that will not be affected by international politics to any extent.

Despite the steel industry's cyclical nature, it is expected to follow its historic growth pattern. Since 1960, this growth has amounted to 2.6 percent annually [75]. Projecting this growth to 1982 would mean that

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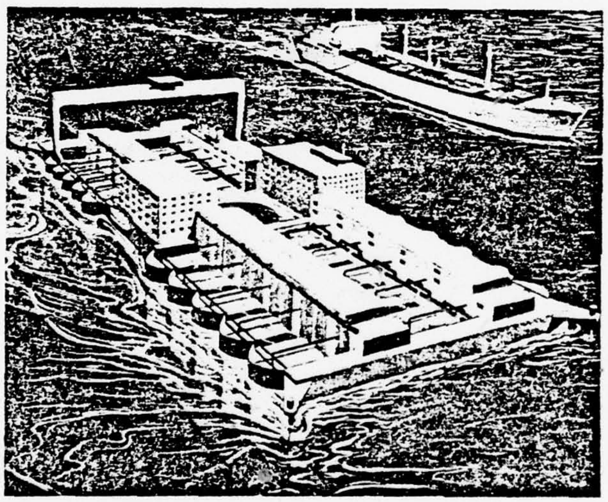
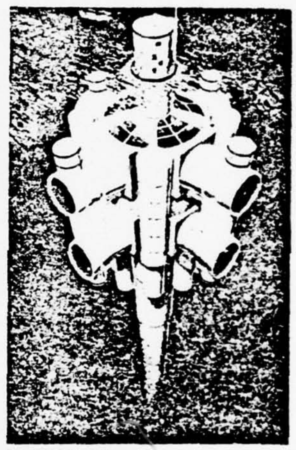
[75] U.S. Department of Commerce, *U.S. Industrial Outlook -1978, with 5-year projections for 200 industries*, U.S. Government Printing Office, Washington, D.C., January 1978.

123.9 million tons of steel would be consumed that year. If imports follow present trends and make up 13 percent of the 1982 demand, then the U.S. market will be producing about 106.8 million tons.

The use of steel for floating structures as large as the proposed ocean thermal energy conversion (OTEC) plants can become too expensive. Platforms with cold-water pipes extending down 2,000 feet could be manufactured from prestressed concrete using the slip-forming techniques developed in the North Sea. Since the energy that these structures are designed to produce will have to compete with energy derived from other sources, relative costs will be extremely important. Studies have indicated that reinforced concrete would be the most economical for satisfying the design specifications [76]. Figure IV-22 shows two designs currently under consideration for floating OTEC plants that use prestressed concrete.



APL design. *It's a roving platform of reinforced concrete, 476 ft long, 196 ft wide and 70 ft deep. Concept is to graze for energy on the warm equatorial ocean waters, and to make ammonia and help conserve NG*



Lockheed design. *It's a submerged spar buoy, 250-ft diameter, 2545-ft high, including the cold water pipe, weighing 300 000 tons. Concept is to send 265 MW of power ashore for the needs of 160 000 residents*

Figure IV-22

PROPOSED OTEC DESIGN CONCEPTS
(Source: Reference [77])

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[76] Dugger, G. L., E. J. Francis, and W. H. Avery, Technical and Economic Feasibility of Ocean Thermal Energy Conversion, Paper presented at Sharing the Sun! Solar Technology in the Seventies, a Joint Conference of the American Section, ISES, and the Solar Energy Society of Canada, Inc., Winnipeg, Manitoba, Canada, August 15-20, 1976.

[77] Miller, Stanton S., How hot is solar energy?, *Environmental Science and Technology 11*(7):651-654, July 1977.

Ferrocement is still not widely accepted in this country, but it is used for several purposes, including boats, elsewhere in the world. Canadians are using it to construct fishing vessels; it is used in New Zealand and Australia for boats and yachts; and there is also a boatyard in Hong Kong which specializes in ferrocement construction.

The demand for ferrocement boats in the United States is reported to be increasing slightly. The price of the 55-foot ferrocement motor sailer (Fibersteel, Inc.) is roughly $65,000 while a comparable vessel of fiberglass costs around $130,000. Thus, as costs of traditional materials increase, ferrocement is expected to enjoy a greater economic advantage. This will be an important factor as the recreational boat market grows and ferrocement gains technical acceptance in the United States.

Two major problems that are facing the ferrocement boatbuilding industry at present are the high density of ferrocement and the current lack of mass production techniques (estimates indicate that mass production techniques are from 3 to 10 years in the future) [78].

A lightweight mortar is currently being developed with a density of 105 pounds per cubic foot, which is comparable to the density of fiberglass. However, there are no mass production methods in current use in the United States. Thus, the process is labor-intensive and relatively expensive. Mass production could reduce the cost considerably by lowering the amount of high-cost labor required.

Owens-Corning, PPG, and Johns-Manville are investigating the development of a fiberglass reinforcement to be used in place of the wire mesh in ferrocement structures. There are presently two problems associated with the use of fiberglass with ferrocement. First, the alkaline mortar attacks the fiberglass. To prevent such problems, a fiberglass resistant to alkali could be developed or the fiberglass could be coated with a resistant material. The second problem is the difficulty in wetting the fiberglass mat with the mortar. This would prevent the formation of a good bond and would result in a weakened structure. If these problems can be solved, ferrocement could replace resins currently used in the production of many fiberglass products, including boats. This would allow the use of a female mold because the fiberglass mats would conform to the mold's shape without deforming as wire mesh does. Such an innovation would make volume production much simpler.

The technology to manufacture 30 or so building products from ferrocement, such as wall panels to replace asbestos heat insulation, exists.

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[78] Interview with Mr. Jack Bauer, Ferroboatbuilders, Inc., Solomons Island, Maryland, 10 April 1978.

Ferrocement will occupy a larger proportion of the market in many areas as engineering confidence increases and as the cost of fiberglass resins increases due to rising oil prices.

Development of a ferrocement boat industry and an increase in the use of reinforced concrete for vessels and other marine structures would not change the marine industries appreciably. The shift would be gradual and would not eliminate other materials in the foreseeable future. However, use of the alternative materials would involve a different frame of reference for construction, maintenance, and inspection. Wide use of ferrocement and prestressed concrete for vessels would require new expertise for designers, fabricators, operators, and inspectors.

5. *Impact on the Coast Guard*

The impact on the Coast Guard will be through the Recreational Boating Safety and Commercial Vessel Safety programs. Specifications for new construction and repairs would be established around the static and dynamic characteristics of the new materials. Inspectors would require additional training and experience to become familiar with the materials and with construction and repair procedures.

Other Coast Guard impacts may be identified in the Port Safety and Security (PSS), Marine Environmental Protection (MEP), and Search and Rescue (SAR) programs, where the use of recreational and commercial vessels is the subject of Coast Guard regulatory and operational activities. PSS and MEP regulations concerning port safety and pollution prevention will have to consider the characteristics of fireproofing and piping/hull interfaces for reinforced-concrete-hulled vessels. SAR operating crews planning to tow ferrocement boats should be aware of all points of strength and weakness on the newer design hulls and rigging.

6. *Conclusions*

- Ferrocement is being used increasingly for the construction of recreational and commercial boats due to its advantages of low capital investment for facilities, low-cost and readily available materials, low-skill labor requirements, ease of fabrication and repair, low maintenance, and fire resistance.

- Prestressed concrete is being used increasingly for a marine construction material due to its low initial and maintenance costs, reduced need for drydocking and inspection, fire resistance, and ability to sustain cyclical loading and fatigue.

- Use of ferrocement and prestressed concrete requires new expertise for designers, fabricators, operators, and inspectors.

- Impacts of the use of these materials will be felt in the Coast Guard on Commercial Vessel Safety, Recreational Boating Safety, Port Safety and Security, Marine Environmental Protection, and Search and Rescue programs.

G. *MINERAL, AGRICULTURAL, AND ENERGY COMMODITY MOVEMENTS*

A major portion of water transportation within the United States, as well as to and from our shores, is used for the carriage of energy resources and food. In 1975, over 80 percent of all waterborne commerce, both foreign and domestic, was involved in these movements. Petroleum, its products, coal, and coke made up 55.2 percent of foreign tonnage and 59.1 percent of domestic tonnage. Ores, sands, aggregates, and grain used the rest.

Water transportation has a close relationship to the production processes of basic materials and agricultural products. As changes in these primary industries develop due to shifts in supply and demand of their raw materials and products, there will be concurrent shifts in the traffic patterns of waterborne commerce.

1. *Causative Factors of Shortages*

Since the need for transportation services is a demand derived from the needs of the materials being transported, changes in transportation will reflect changes in the basic commodity markets.

Petroleum will be used less for its energy content and used more as a basic source in the manufacture of chemicals and plastics. Coal will also follow this pattern after it has passed through a period as a replacement for petroleum as an energy source. Due to environmental considerations, more western coal will be used for ruel.

Shifts in reliance on foreign sources of ore will generate shifts in international and domestic movements of these materials. The same will result from changes in exports of grains and other agricultural commodities.

Crude oil movements will increase to the end of the 20th century and then diminish toward the middle of the 21st century. The use of Very Large Crude Carrier (VLCC) and Ultra Large Crude Carrier (ULCC) tankers will diminish during this period. As petroleum becomes more used for its chemical components and derived products by the chemical and plastics industry, there will be an increase in barge and coastal tanker traffic. These "drugstore" ships will establish new traffic patterns.

Ore traffic will shift depending on the nature of imports, exports, and domestic movements. Each particular material will establish its own pattern. The total effect on transportation needs will be determined by aggregating individual commodity shifts.

As the Lesser Developed Countries (LDCs) progress, they will export more processed materials and less raw materials. This will apply especially to crude oil and ores. Environmental restrictions in developed

countries, cheap electrical power in the LDCs, and the need of the LDCs to expand their industrial base will contribute to the shift of at least intermediate processing facilities from developed to lesser developed countries.

Grain production and U.S. exports will increase as the world's demand for food grows in the remainder of this century. U.S. consumption will increase at a lower rate than U.S. production. The surplus will be shipped abroad.

An interesting interrelationship exists between materials and transportation, especially water transportation. Figure IV-23 shows the amounts of materials that are transported in, out, and within the United States. Of particular interest is the first graph which shows the volume of waterborne imports of petroleum, coal, and ores. The exports graph shows all other shipments at 51 percent; this is primarily grain.

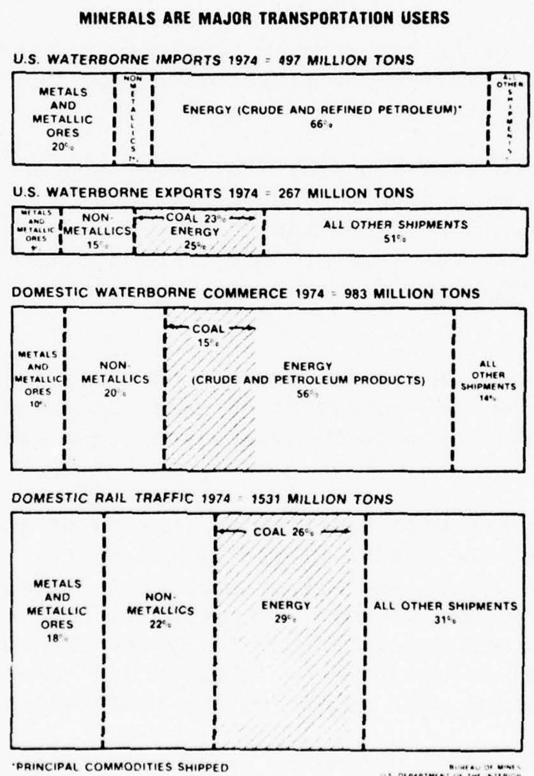

Figure IV-23

TONNAGES OF MINERALS TRANSPORTED BY RAIL AND WATER, INCLUDING IMPORTS AND EXPORTS, 1974

(Source: Reference [79])

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[79] U.S. Department of the Interior, Bureau of Mines, Introduction - A Chapter from Mineral Facts and Problems, 1975 Edition, Preprint from Bulletin 667, U.S. Department of the Interior, Washington, D.C.,1975.

The uses by the transportation industry in the consumption of the products of other industries is the reverse of this relationship. Figure IV-24 shows what percentage of those industries' outputs is consumed by the transportation industry.

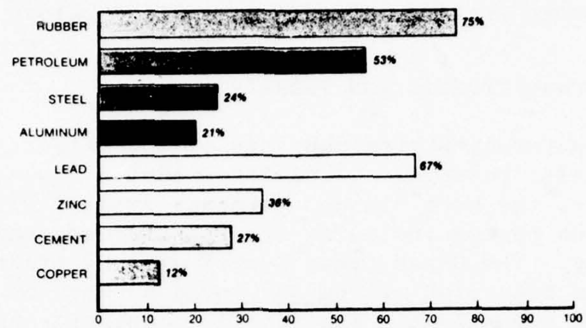

Figure IV-24

TRANSPORTATION INDUSTRY'S CONSUMPTION OF OTHER INDUSTRIES' PRODUCTS, 1973
(Source: Reference [80])

Table IV-32 provides a breakdown by category of the principal commodities in waterborne commerce.

Table IV-32

PRINCIPAL COMMODITIES IN WATERBORNE COMMERCE, 1975
(Source: Reference [81])

Commodity Category	In Waterborne Commerce		
	Total (percent)	Foreign (percent)	Domestic (percent)
Petroleum and products	43.6	44.7	42.7
Coal and coke	13.8	10.5	16.4
Iron ore and iron and steel	8.9	9.8	8.2
Sand, gravel and stone	6.5	1.8	10.3
Grains	6.6	10.6	3.5
Logs and lumber	2.9	3.2	2.6
Chemicals	5.1	5.0	5.2
Seashells	0.9	0.0	1.6
All other commodities	11.7	14.4	9.5

[80] U.S. Department of Transportation, *National Transportation: Trends and Choices (to the year 2000)*, U.S. Government Printing Office, Washington, D.C., January 1977.

[81] Department of the Army, Corps of Engineers, *Waterborne Commerce of the United States, Calendar Year 1975, Part 5, National Summaries.*

2. *Current Status and Potential Developments*

The domestic transportation of commodities can be classified by routes. The basic categories are: inland waterway; domestic and international Great Lakes; domestic ocean (including contiguous and noncontiguous); and international ocean traffic. These are defined below.

a. *Inland Waterway Traffic and Vessels*

The inland waterway system consists of approximately 25,000 miles of navigable channels, reservoirs, and lakes [80]. However, for the purposes of this analysis, the term "inland waterway system" will refer to the Mississippi River System including its tributaries, and the Gulf Intracoastal Waterway. The Great Lakes System will be treated separately. A breakdown of the ton-miles of freight moved on both of these systems and the waterways on the Atlantic and Pacific coasts for the years 1966 to 1975 is shown in Figure IV-25.

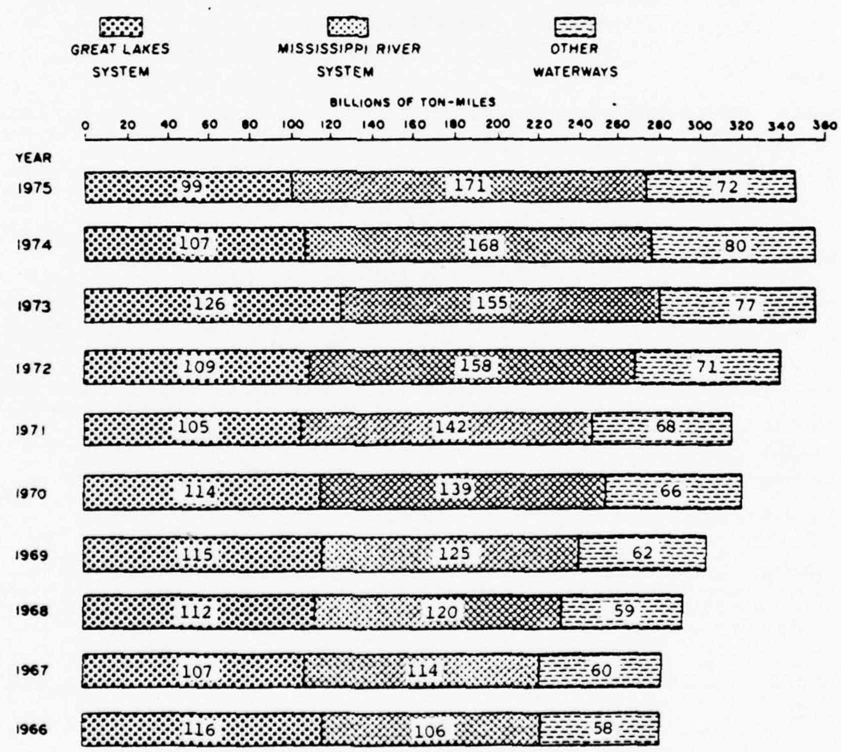

Figure IV-25

TON-MILES OF FREIGHT CARRIED ON U.S. WATERWAYS, 1966-1975
(Source: Reference [80])

As indicated by Figure IV-25, the Mississippi River System has shown a 61-percent increase in ton-miles in the 10-year period from 1966 to 1975. The Great Lakes System has experienced a 14-percent decrease, and all other domestic waterways have posted an increase of 24 percent for the same time frame. Table IV-33 lists projections of growth of major commodity classes on the inland waterways to 1980 and 1990.

Table IV-33

COMMODITY FLOW PROJECTIONS — TOTAL U.S. INTERNAL WATERS
(Source: Reference [80])

Commodity Class	Short Tons (in 000)			Percentage Increase
	1975	1980	1990	1975-1990
Grain and farm products	35,384	37,430	46,085	30
Coal and lignite	132,070	147,918	187,389	42
Crude petroleum	79,142	80,637	84,964	7
Petroleum products	189,638	214,859	272,242	44
Nonmetallic minerals	87,529	92,169	104,356	19
Metal ores	5,367	5,738	10,678	99
Primary metals	13,712	14,673	17,655	29
Metal products and machinery	3,125	3,616	4,813	54
Chemicals and products	46,983	57,837	87,676	87
Lumber	2,206	2,432	3,007	36
Pulp, paper, and allied products	20,933	24,910	35,876	71
All other	40,525	46,843	63,022	56
Total	656,614	729,062	917,763	40

Coal and lignite shipments, which currently make up 20 percent of the total tonnage shipped via waterways, are expected to increase by 42 percent between 1975 and 1990. These increases are due, in part, to the National Energy Plan's implied goals for coal transportation [82]. The demand for coal for new utilities committed for construction between 1978 and 1985 is expected to exceed 360 million tons per year. Of the 224 fossil-fuel plants committed to be built by 1990, 67 percent are to use coal as fuel [83]. Petroleum products, making up 29 percent of the total tonnage of water-transported commodities, are projected to increase by 44 percent from 1975 to 1990; crude petroleum movements are expected to increase by only 7 percent during the same period. These two facts illustrate the increasing tendency to locate production facilities closer to the raw

[82] U.S. Department of Transportation, *Transporting the Nation's Coal—A Preliminary Assessment*, Report to the Secretary of Transportation from the Coal Transportation Task Force, January 1978.

[83] Rittenhouse, R. C., A profile of new generating capacity, *Power Engineering 80*(4):76-82, April 1976.

material sources and further from the product markets. While other commodities in Table IV-33 show some large percentage changes, all of the remaining commodities make up a little over half of the tonnage moved in 1975.

The inland waterway fleet consists of shallow-draft towboats and barges, designed to minimize the constraints of physical features such as locks, bridges, and narrow, shallow channels, while maximizing cargo-carrying capacity. The current composition of the fleet and its projected growth are shown in Table IV-34. Tables IV-35 and IV-36 provide breakdowns of towboat projections by horsepower and of barge projections by type and size, respectively.

Table IV-34

CURRENT AND PROJECTED INLAND WATERWAY FLEET
(Source: Reference [80])

Vessel Type	1975	1980	1990	Percent Increase 1975-1990
Towboats				
Number	2,404	2,488	2,920	21
Total horsepower (in 000)	3,226	3,555	4,530	40
Average horsepower	1,340	1,429	1,550	16
Barges				
Dry cargo	17,345	19,435	24,075	38
Tank	2,903	3,498	4,419	52
Total barges	20,248	22,933	28,494	52
Total capacity	27,150	31,200	39,600	46
Average capacity	1,340	1,360	1,390	4

Table IV-35. INLAND WATERWAY TOWBOAT PROJECTIONS
(Source: Reference [80])

	1975		1980		1990	
Towboat Class (horsepower)	Total Number	Operational Number	Total Number	Operational Number	Total Number	Operational Number
300	748	150	748	150	840	150
600	436	250	436	250	488	250
1,200	610	555	610	595	660	650
1,800	210	103	215	105	300	145
2,500	91	93	93	128	128	73
3,300	134	88	163	59	187	124
4,300	73	49	88	59	128	76
5,000	36	36	44	44	61	61
5,700	32	32	39	39	55	55
7,000	22	22	28	28	37	37
8,400	11	11	15	15	15	19
9,000	2	2	3	3	6	6
10,100	4	4	6	6	11	11
Total Number	2,404	1,354	2,488	1,446	2,920	1,657

Table IV-36

INLAND WATERWAY BARGE PROJECTIONS
(Source: Reference [80])

Type	Size	1975		1980		1990	
		Number	Cost $1000/day	Number	Cost $1000/day	Number	Cost $1000/day
OH	245 x 35	245	22.8	245	22.8	306	28
OH	195 x 35	5,490	417.2	6,300	478.2	8,730	663
OH	175 x 26	2,890	150.3	2,900	155	2,900	155
OH	120 x 30	1,172	46.9	1,170	46	1,170	46
CH	195 x 35	4,650	558.0	5,950	714.0	7,600	910
DK	200 x 50	348	38.3	350	38	435	47
DK	195 x 35	510	28.8	520	39	924	69
DK	150 x 32	810	42.1	810	42	810	42
DK	100 x 26	1,230	38.1	1,200	38	1,200	38
TN	290 x 53	573	114.6	688	138	867	174
TN	240 x 50	760	136.8	910	164	1,147	207
TN	185 x 54	322	51.5	320	51	320	51
TN	195 x 35	790	86.9	1,120	123	1,625	178
TN	135 x 40	458	41.2	460	41	460	41
	Total	20,248	1,783.5	22,933	2,084	28,494	2,649

OH = open hopper *CH = covered hopper*
DK = deck *TN = tank*

The open-hopper barges (see Table IV-36) are used for coal, sand and gravel, ores, and metal products. The covered-hopper barges carry grain, chemicals, and paper and allied products. The deck barges are used for construction, terminal operations, and moving large, bulky items. The tank barges carry liquid cargo such as petroleum, petroleum products, and chemicals.

b. Great Lakes Traffic and Vessels

The Great Lakes System includes the five Great Lakes, the St. Lawrence River, and all connecting locks and channels. Large-quantity movements through the Great Lakes System are made up of only a few types of commodities. Transportation of goods on the 2,342-mile system is accomplished by two types of vessels, the lakers and the ocean fleets. The laker fleet is designed specifically for Great Lakes operation. The lakers are characterized by a high-block coefficient with a blunt bow and stern, and a flat bottom [84]. Bulk commodities, both dry and liquid, are their cargoes. The ocean fleet is composed of that portion of ocean vessels that can be accommodated by the St. Lawrence and Welland Locks. Their cargoes are bulk commodities and general freight.

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[84] Schenker, E., H. M. Mayer, and H. C. Brockel, *The Great Lakes Transportation System*, Technical Report #230, University of Wisconsin Sea Grant College Program, January 1976.

Table IV-37 provides the size of the domestic Lakes fleet by vessel type and trip capacity. Bulk carriers made up almost the entire domestic Lakes fleet in 1975 and emphasize the impact of bulk commodities on Lakes traffic.

Table IV-37

PRINCIPAL COMMERCIAL ELEMENTS IN THE DOMESTIC LAKES FLEET, 1975
(Source: Reference [80])

Vessel Type	Number	Trip Capacity (long tons)
Dry bulk freighter	209	3,196,000
Self Unloaders	79	1,469,000
Tankers	58	329,000
Total	345	4,994,000

The major commodities carried by the domestic Lakes fleet include coal, limestone, grain, iron ore, and petroleum products. Coal shipments include bituminous coal and anthracite. Grain movements are primarily wheat, oats, barley, corn, rye, and soybeans. Selected petroleum products and crude petroleum that moved as bulk cargo were included as petroleum. The 1975 status of domestic movements of these commodities and projections to the year 2000 are presented in Table IV-38.

Table IV-38

CURRENT AND PROJECTED GREAT LAKES COMMODITY MOVEMENTS
(millions of short tons)
(Source: Reference [84])

Commodity	1975	1980	1985	1990	1995	2000	% Increase 1975-2000
Iron Ore	85.3	93.0	104.9	117.4	132.8	150.3	76
Coal	45.3	48.8	52.4	56.6	62.1	68.6	51
Limestone	35.6	38.6	42.6	47.6	54.1	62.2	74
Petroleum	5.5	6.3	7.2	8.2	9.3	10.6	93
Grain	2.4	2.7	3.0	3.3	3.7	4.1	71
Total	174.1	189.4	210.1	233.1	262.0	295.8	70

Of the major commodities moving on the Great Lakes System, all but grain are concerned with the production of steel. The projections of the Department of Transportation, made approximately one year later than those in Table IV-38, are presented in Table IV-39 for comparison.

Table IV-39

PROJECTED U.S. DOMESTIC COMMODITY MOVEMENTS ON THE GREAT LAKES SYSTEM (millions of short tons)
(Source: Reference [80])

Commodity	1975	1980	1990	% Increase 1975-1990
Iron ore	85.4	93.1	116.7	37
Coal	47.5	47.8	59.0	24
Limestone and mine products	39.1	42.5	52.0	33
Domestic grain	2.5	2.8	3.5	40
Other	19.6	22.8	30.6	56
Total	194.1	209.0	261.8	35

The requirements for dry bulk transportation on the Lakes and the fleet that has been projected to satisfy these requirements are presented in Tables IV-40 and IV-41, respectively. Analysis of the figures indicates that approximately 50 percent of the 1990 dry bulk fleet will be in excess of 700 feet in length, but will carry over 70 percent of the dry bulk cargo. The increase in the projected number of ships over 700 feet is indicated in the 14 ships of that size on order in 1975 when compared to only one vessel less than 400 feet on order [80]. The 1990 dry bulk fleet will decrease 4.5 percent in number of vessels, but will increase over 30 percent in trip capacity.

Table IV-40

ESTIMATED DRY BULK FLEET REQUIREMENTS
(Source: Reference [80])

	Long tons		
Capacity	1975-1980	1980-1990	1975-1990
Estimated Capacity Required	4,902,000	6,148,000	6,148,000
Less Beginning Capacity	4,665,000	4,902,000[1]	4,665,000
New Capacity Required	237,000	1,246,000	1,483,000
Add Replacement	768,000	550,000	1,318,000
Total New Building Required	1,005,000	1,796,000	2,280,000

[1]*Assumes capacity additions and replacements in service by 1980.*

Table IV-41

ESTIMATED DRY BULK FLEET--1990
(Source: Reference [80])

Vessel Length (Feet)	No. Ships	% Total Ships	Capacity (Long Tons)	% Total Capacity
Under 400	28	10.2	92,764	1.5
400-499	6	2.1	48,822	0.1
500-549	1	0.3	10,539	0.1
550-599	6	2.1	70,314	1.1
600-649	54	19.7	829,818	13.4
650-699	34	12.4	716,278	11.6
700-730	106	38.6	2,653,392	43.1
731-849	12	4.3	330,036	5.3
850-948	12	4.3	534,000	8.6
950-Over	15	5.4	866,250	14.0
Total	274	100.0	6,152,213	100.0

c. Domestic Ocean Traffic and Vessels

Domestic ocean trade includes all domestic freight movements along, to, and from the Atlantic, Pacific, and Gulf coasts (contiguous); and to and from Hawaii, Alaska, Puerto Rico, and the Virgin Islands (noncontiguous). These shipments are carried on several types of vessels and are composed of a wide variety of products. In accordance with the cabotage principle of the Jones Act of 1920, all domestic ocean trade must move on U.S. flag vessels. Figure IV-26 provides a comparison between foreign and domestic traffic through U.S. coastal ports. It is clear that foreign trade has been increasing more rapidly than domestic trade.

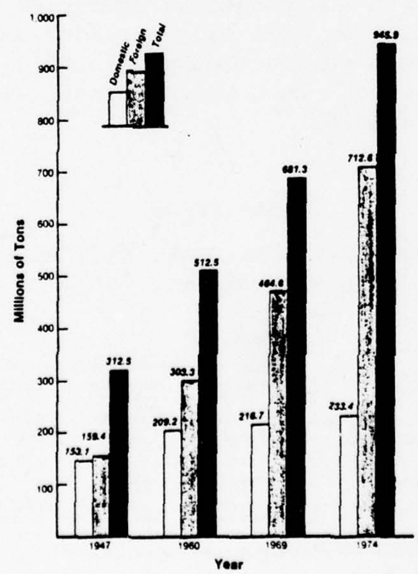


Figure IV-26

COMPARISON OF DOMESTIC AND FOREIGN TRADE THROUGH U.S. COASTAL PORTS
(Source: Reference [80])

Table IV-42 provides a summary of the overall tonnage carried in domestic ocean trade during 1974. A breakdown for commodity classes and trade areas is also given. It should be noted that petroleum dominates the trade with over 75 percent of the total tonnage moved.

Table IV-42

SUMMARY OF OVERALL TONNAGE CARRIED IN DOMESTIC OCEAN TRADE FOR 1974[1]
(thousands of short tons, figures and totals rounded)
(Source: Reference [80])

Trade Area	Nonpetroleum		Petroleum		Dry Cargo		Total Tonnage	Percent Carried by Self-propelled Vessels
	Self-propelled Vessel	Barge	Self-propelled Vessel	Barge	Self-propelled Vessel	Barge		
Coastal	8,324.8	3,155.7	106,746.8	31,129.0	4,735.9	19,585.5	173,677.8	68.99
Noncontiguous	2,342.6	507.6	38,976.2	816.5	9,983.2	2,588.1	55,214.1	92.91
Intercoastal	779.8	0	1,492.3	0	2,009.1	158.6	4,439.8	96.43
Total	11,447.2	3,663.3	147,215.4	31,945.5	16,728.2	22,332.2	233,331.8	75.16
Percent of total	4.91	1.58	63.09	13.69	7.16	9.57	100	–

[1] *Does not include trade between Puerto Rico, the Virgin Islands, and U.S. ports.*

Projected domestic ocean trade by commodity group is presented in Table IV-43. The substantial difference between the percentage increase for total tonnage and that for total tonnage-miles is due to the increased movement of petroleum and its products. Such shipments will result in shorter hauls because of their relatively closer origins such as from North Atlantic wells. The transport of oil from the southern end of the Trans-Alaskan Pipeline System to west coast ports is also included and could require up to 35 tankers. Eight have been constructed to date.

Table IV-43

PROJECTED DOMESTIC OCEAN AND MISCELLANEOUS WATERWAYS[a] *TRADE*
(Source: Reference [80])

Commodity Group	1975	1980	1990	% Increase 1975-1990
Fuels and lubricants	213,967	290,245	560,607	162
Durable manufactures	34,829	41,970	61,833	78
Coal	30,783	34,275	42,899	39
Crude oil	21,214	25,848	32,841	55
Mining products	16,302	18,992	25,693	58
Chemicals and allied products	12,475	17,393	31,418	152
Raw and refined sugar	2,743	3,375	4,712	72
Lumber	2,348	2,917	4,348	85
Canned fruits and vegetables	1,340	1,719	2,501	87
Cash grains	1,297	1,447	1,864	44
Primary iron and steel products	1,279	1,462	1,872	46
Agricultral products NEC	652	754	981	50
Nondurable manufactures	548	601	710	30
Fabricated metal products	503	568	705	40
Paper and paper products	237	320	552	133
Grain mill products	160	197	286	79
Nonferrous primary metal products	160	77	122	-24
Metal ore	5	8	16	220
Iron ore	2	4	10	400
Total tons	340,744	442,172	773,970	127
Total ton-miles (billions)	249	280	351	41

[a] Includes traffic on Sacramento, Columbia & Savannah Rivers & the N.Y. State Barge Canal that were not included in inland waterway projections. Excludes Gulf to Gulf traffic which is included in those projections.

A breakdown of the U.S. flag domestic oceangoing fleet, by area of operation and type of vessel, is presented in Table IV-44.

Table IV-44

JUNE 1975 U.S. FLAG DOMESTIC OCEANGOING FLEET
(tonnage in thousands of long tons)
(Source: Reference [80])

	Total		Combination Passenger/Cargo		Freighters		Tankers	
Trade	No.	DWT	No.	DWT	No.	DWT	No.	DWT
Coastal	153	4,653	–	–	17	354	136	4,299
Intercoastal	11	271	–	–	3	54	8	217
Noncontiguous	41	763	1	7	28	417	12	339
Total	205	5,687	1	7	48	825	156	4,855

The vessels listed in Table IV-44 represent 38 percent of the 543 active U.S. flag vessels in 1975. The remaining 62 percent, or 338, of the active U.S. flag vessels are used in international commerce. The container trade, including LASH (Lighter Aboard Ship), SEABEE (Sea Barge), RO/RO (Roll on/Roll off), containership, and various combinations, has shown an increase in the numbers of equipments involved. Table IV-45 shows the number of vessels and cargo vehicles involved.

Table IV-45

U.S. INTERMODAL EQUIPMENT SURVEY
(Source: Reference [80])

Category	1973	1974	1975	% Increase 1973-1975
Vessels				
Containership	98	95	97	-1
Partial Containership	59	60	53	-10
LASH	14	20	20	42
LASH Feeder	0	3	4	400
SEABEE	3	3	3	0
RO/RO (Roll on/Roll off)	5	6	6	20
Combination Container/RO/RO	4	4	4	0
Cargo Vehicles				
Containers	366,033	441,854	471,675	29
Chassis	112,304	121,104	124,476	11
LASH Barges	1,808	2,961	3,110	72
SEABEE Barges	246	246	246	0
RO/RO Trailers	2,239	2,236	2,826	26

d. International Ocean Traffic and Vessels

International ocean trade includes all freight movements from foreign to U.S. ports (imports) and from U.S. to foreign ports (exports). This trade moves via both U.S. and foreign flag carriers.

The total volume of U.S. waterborne trade, both imports and exports, is illustrated in Figure IV-27 which is based on the data in Table IV-46. Projections to 1990 are shown in Figure IV-27 and to 2000 are shown in Table IV-46.

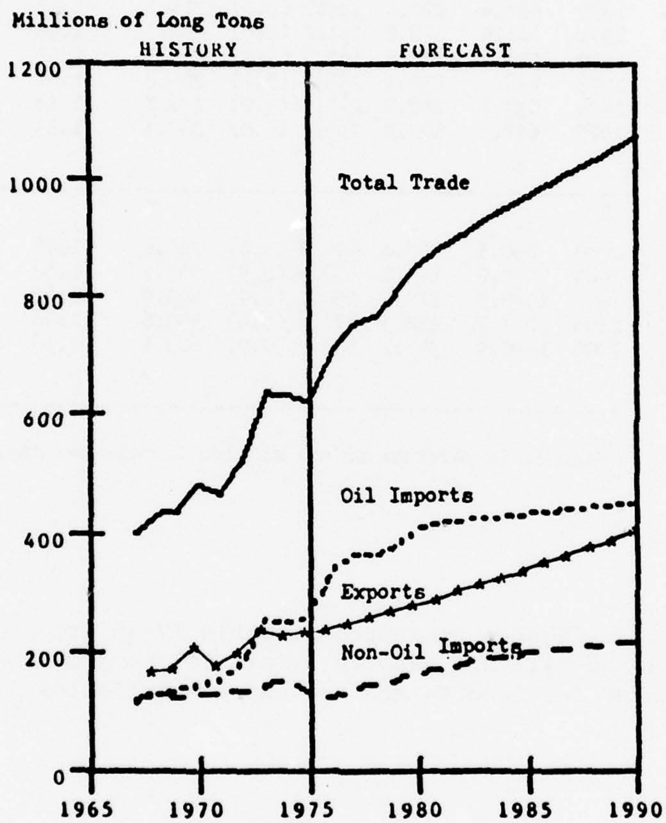


Figure IV-27

U.S. WATERBORNE TRADE, HISTORY/FORECAST
(Source: Reference [85]

[85] U.S. Department of Commerce, Maritime Administration, *A Long-Term Forecast of U.S. Waterborne Foreign Trade 1976-2000, Volume 1, Summary*, PB-274 601, National Technical Information Service, Springfield, Virginia, November 1977.

Table IV-46

U.S. WATERBORNE FOREIGN TRADE, 1967-2000
(millions of long tons)
(Source: Reference [85])

	Year	Total Trade	Non-Oil Imports	Oil Imports*	Exports	Import Export Ratio
HISTORY	1967	396.6	117.4	111.8 (2.2)	167.3	1.37
	1968	426.1	127.1	125.4 (2.5)	173.6	1.47
	1969	435.7	121.7	136.0 (2.7)	178.0	1.45
	1970	481.4	127.6	139.7 (2.8)	214.1	1.25
	1971	461.9	128.6	151.0 (3.0)	182.3	1.53
	1972	518.8	130.6	182.7 (3.6)	205.5	1.52
	1973	638.0	139.9	253.3 (5.0)	244.8	1.61
	1974	633.7	147.7	249.9 (4.9)	236.1	1.68
	1975	622.3	127.9	254.1 (5.0)	240.3	1.59
FORECAST	1980	850.5	160.0	404.9 (8.0)	285.6	1.98
	1985	970.2	195.7	430.9 (8.5)	343.7	1.82
	1990	1075.5	215.4	450.2 (8.9)	409.9	1.62
	1995	1228.7	258.3	474.8 (9.4)	495.6	1.48
	2000	1420.9	317.1	500.7 (9.9)	603.1	1.36

*Figures in parenthesis are million barrels per day.

The total trade figures presented in Table IV-46 are broken down by imports (non-oil and oil) and exports. Detailed projections by commodity group are presented for imports and for exports in Tables IV-47 and IV-48, respectively.

Table IV-47

U.S. WATERBORNE TRADE FORECAST, IMPORT GROUPS, 1975-2000
(Source: Reference [85])

Import Group	Percent in 1975 % of Total	Percent in 1975 % of Non-oil	History 1975	1980	1990	2000	Annual % Growth 1967-1975	Annual % Growth 1975-2000
			Thousands of Long Tons					
Meat	0.2	0.6	771	1376	2092	5179	2.5	5.8
Sugar	1.3	3.9	4985	8008	10000	12489	-2.0	3.7
All Other Foods	1.6	4.6	5927	6071	6069	6067	-3.0	0.1
Beverages	0.3	0.8	962	1545	2442	3859	6.7	5.7
Tobacco	0.0	0.1	174	178	311	546	4.1	4.7
Hides and Skins	0.0	0.0	24	31	28	25	-7.2	0.2
Oilseeds, Nuts and Kernels	0.0	0.0	17	19	8	4	-27.2	-5.6
Crude Rubber	0.2	0.6	774	1073	1633	2485	4.9	4.8
Wood, Lumber and Cork	0.5	1.5	1914	2748	1719	1074	-4.8	-2.3
Pulpwood and Waste Paper	0.1	0.2	286	245	126	65	-9.4	-5.8
Textile Fibers	0.0	0.1	152	272	121	54	-11.8	-4.1
Stone, Sand and Gravel	2.0	6.0	7722	10523	11315	12166	1.5	1.8
Other Crude Minerals	1.8	5.2	6701	8688	13672	21517	3.5	4.8
Metallic Ores and Scrap	15.8	47.1	60213	60704	71615	84486	-0.1	1.4
Animal and Vegetable Matl.	0.1	0.2	244	267	267	267	-1.9	0.4
Coal	0.6	1.8	2291	3454	9126	24117	43.8	9.9
Petroleum	66.5	-	254093	404889	450245	500682	9.5	2.8
Gas	0.4	1.0	1340	3540	7929	17757	69.7	10.9
Animal & Veg. Fats & Oils	0.3	0.8	1011	1513	2287	3456	10.5	5.0
Chemicals	2.0	5.9	7608	13335	28010	58838	9.0	8.5
Leather	0.0	0.0	13	35	52	76	-3.8	7.3
Rubber Manufactures	0.1	0.2	203	433	735	1247	15.3	7.5
Wood Products	0.4	1.1	1449	2489	2577	2668	-3.3	2.5
Paper Products	0.4	1.1	1431	2039	1968	1900	-6.7	1.1
Textile Yarns and Fabrics	0.1	0.4	562	763	605	479	-3.5	-0.6
Building Materials	0.7	2.1	2741	6814	10640	16613	11.2	7.5
Refractory Building Materials	0.0	0.1	121	363	691	1317	-1.4	10.0
Mineral Manufactures	0.0	0.0	59	86	148	254	11.4	6.0
Glass	0.0	0.1	156	186	85	39	-9.0	-5.4
Glassware, Pottery & Gems	0.1	0.2	217	279	459	757	2.2	5.1
Iron and Steel	2.9	8.6	11043	12426	12322	12218	0.7	0.4
Nonferrous Metals	0.2	0.6	704	696	542	422	-4.7	-2.0
Metal Manufactures	0.3	0.9	1137	1744	2236	2865	4.2	3.8
Machinery	0.4	1.2	1506	2337	5044	10889	5.7	8.2
Transportation Equipment	0.5	1.6	2059	3410	4816	6801	11.2	4.9
Fixtures	0.0	0.0	22	39	37	34	-3.2	1.8
Clothing, Shoes and Luggage	0.1	0.4	482	722	1110	1707	7.4	5.2
Furniture	0.0	0.1	124	186	249	333	7.3	4.0
Scientific Equipment	0.0	0.0	62	101	222	491	6.6	8.6
Miscellaneous Manufactures	0.1	0.4	508	1094	1923	3377	3.4	7.9
Miscellaneous Transactions	0.1	0.2	204	170	170	170	6.4	-0.7
Total	100.0		382008	564888	665643	817792	5.8	3.1

Table IV-48

U.S. WATERBORNE TRADE FORECAST, EXPORT GROUPS, 1975-2000
(Source: Reference [85])

Export Group	Percent in 1975	History 1975	1980	Forecast 1990	2000	Annual % Growth 1967-1975	1975-2000
	%	Thousands of Long Tons					
Grains	29.9	71747	82448	109684	145916	6.7	2.9
Animal Feeds	2.4	5678	8923	16198	29401	6.3	6.8
All Other Foods	1.0	2512	2792	3534	4474	2.4	2.3
Beverages	0.0	89	153	276	500	15.9	7.1
Tobacco	0.2	369	423	539	687	1.0	2.5
Oilseeds and Nuts	5.3	12799	15068	21742	31372	6.3	3.7
Wood, Lumber and Cork	4.8	11495	16711	26491	41994	5.1	5.3
Pulp and Waste Paper	1.2	2826	3356	5152	7908	5.9	4.2
Manmade Fibers	0.0	109	242	692	1977	11.7	12.3
Natural Fibers	0.5	1127	1498	1575	1656	0.3	1.6
Crude Fertilizers & Minerals	7.3	17475	22268	32610	47755	3.1	4.1
Metallic Ores and Scrap	4.1	9846	9939	13958	19602	-2.1	2.8
Other Crude Materials	0.3	741	809	919	1044	0.9	1.4
Coal	24.5	58898	58829	76738	100099	3.2	2.1
Petroleum	4.1	9792	9612	8647	7779	-3.9	-0.9
Gas	0.4	922	922	884	847	20.5	-0.3
Animal & Vegetable Oils & Fats	0.7	1685	2134	2999	4215	0.5	3.7
Chemicals	6.4	15412	21442	36879	63428	4.7	5.8
Leather	0.0	18	26	45	77	9.2	6.0
Rubber Manufactures	0.1	128	145	199	272	8.6	3.2
Wood Manufactures	2.5	6030	10284	21328	44233	18.7	8.3
Paper Manufactures	0.8	1971	2837	4483	7085	1.9	5.3
Textile Yarns and Fabrics	0.2	377	785	1628	3376	9.7	9.2
Building Materials	0.2	528	770	1151	1721	5.3	4.8
Glass	0.0	70	149	318	676	3.8	9.5
Glassware, Pottery & Gems	0.0	76	110	168	255	2.7	5.0
Iron and Steel	0.8	1969	5259	9412	16846	4.6	9.0
Nonferrous Metals	0.2	503	798	1466	2766	1.4	7.1
Utensils	0.0	14	25	43	75	1.9	6.9
Metal Manufactures	0.2	479	817	1464	2624	7.5	7.0
Nonelectrical Machinery	1.0	2489	3225	4536	6382	8.3	3.8
Electrical Machinery	0.2	523	756	1171	4814	10.6	5.1
Transportation Equipment	0.5	1242	1424	1898	2529	7.6	2.9
Heating and Plumbing Equip.	0.0	23	31	48	75	1.2	4.8
Furniture	0.0	24	42	76	138	3.4	7.2
Travel Goods	0.0	3	6	11	20	12.6	7.9
Clothing	0.0	21	17	8	4	-2.0	-6.4
Footwear	0.0	2	2	3	4	8.0	2.8
Instruments	0.0	98	165	296	531	7.6	7.0
Miscellaneous Manufactures	0.1	205	316	529	887	5.9	6.0
Miscellaneous Transactions	0.0	18	24	35	50	5.3	4.2
Total	100.0	240332	285581	409851	603093	4.1	3.7

An analysis of the total international waterborne trade data shows that exports made up 38 percent of the total. This figure is expected to decline as the import of oil increases to the year 2000. If the importation of oil continues at the projected rate, the ratio of tons imported to tons exported will reach 1.98 in 1980. After 1980, the amount of oil imported is expected to decline and thus reduce the ratio to 1.36 by 2000.

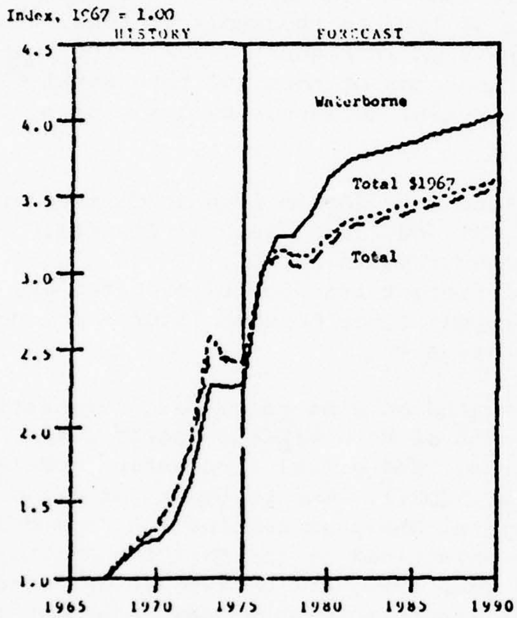
Shown below are Figures IV-28A through IV-28M, taken from a Maritime Administration report [85], which present detailed pictures of selected imported and exported commodities. Each of these figures contains a graphical representation and an accompanying table containing base data.

[The vertical scale on Figures IV-28A through IV-28M is indexed to the 1.00 base value for the trade volume of 1967 in thousands of tons. In some cases, additional data are graphed as in Figure IV-28A. The "waterborne" and "total" graphs refer to thousands of tons and the "total $1967" refers to the trade volume in constant 1967 dollars, and again using 1967 as a base with a value of 1.00.]

[The historical portion of the base data for imports is derived from Bureau of the Census reports SA 305, FT 450, "U.S. General Imports," and that for exports is derived from Census reports SA 705, FT 450, "U.S. Exports." Historical percentages of freight transported by water are derived from the values of goods shipped, since tonnage figures are not available for all modes of transportation.]

[The projections, to 1990, were based on a microeconomic forecasting procedure developed within the Division of Economic and Operational Analysis of the Department of Commerce. The actual forecasting models were developed by Data Resources, Inc. (DRI). The procedure utilized by the Division of Economic and Operational Analysis combines DRI's models with the waterborne trade data base maintained by the Maritime Administration. Waterborne forecasts, to the year 1990, are derived in one step utilizing DRI's models. No explicit assumptions were made regarding the percentage of total trade volumes that will be waterborne. A time variable was introduced into the micro-models to reflect the continuing shifts in transportation mode that were noted in the 1967 to 1975 data. The forecast of waterborne trade volume was extended to the year 2000 by extrapolating the 1980-1990 growth trend.]

Petroleum represents 66 percent of the total U.S. waterborne import volume and 98 percent of U.S. total waterborne fuel imports. Figure IV-28A presents details of petroleum and petroleum products importation.



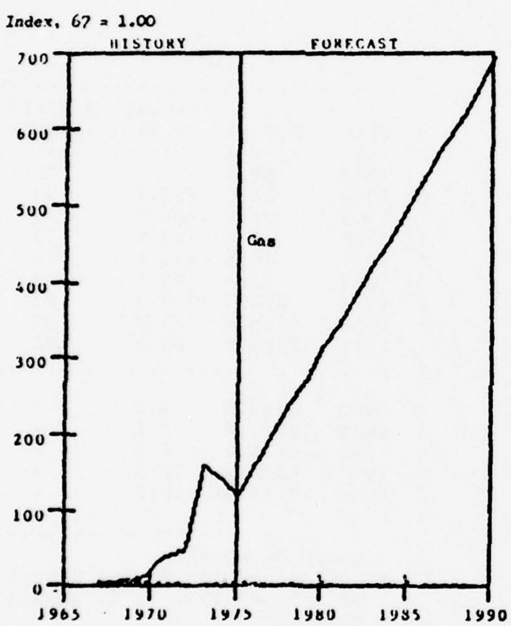
	YEAR	000 LT	ANNUAL % GR	% WATER-BORNE*
	1967	111844.8	-	88
H#	1968	125380.8	12.1	88
I	1969	136014.9	8.5	86
S	1970	139669.2	2.7	82
T	1971	151042.9	8.1	78
O	1972	182650.0	20.9	77
R	1973	253284.6	38.7	82
Y	1974	249885.4	-1.3	82
	1975	254092.6	1.7	84
F				
O				
R	1980	404888.7	9.8	-
E	1985	430862.7	1.3	-
C	1990	450244.9	0.9	-
A	1995	474794.2	1.1	-
S	2000	500682.1	1.1	-
T				

* BASED ON VOLUME.
\# SOURCE: BUREAU OF THE CENSUS. SA 305, FT 150, "U.S. GENERAL IMPORTS".

Figure IV-28A

U.S. WATERBORNE IMPORTS OF PETROLEUM AND PETRIOLEUM PRODUCTS
(Source: Reference [85])

The emergence and resulting growth of the commercial LNG fleet is a function of high demand for gas imports. The imports increased over 150-fold between 1967 and 1973 (see Figure IV-28B). In the next two years growth declined, primarily as a result of OPEC price hikes. A phaseout of domestic price controls would suggest a downward adjustment of the projected import quantities.



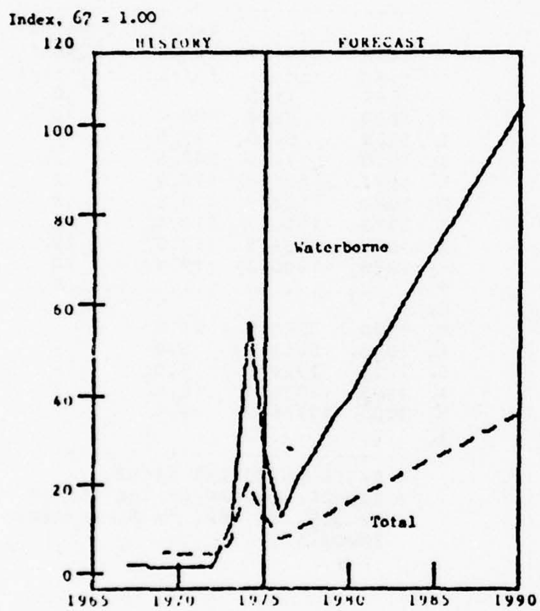
	YEAR	000 LT	ANNUAL % GR	% WATER-BORNE*
	1967	11.5	-	0
H#	1968	28.8	150.7	1
I	1969	51.0	77.5	1
S	1970	174.9	242.6	2
T	1971	484.8	177.2	2
O	1972	537.3	10.8	3
R	1973	1818.1	238.4	15
Y	1974	1565.5	-13.9	19
	1975	1340.3	-14.4	10
F				
O				
R	1980	3540.2	21.4	-
E	1985	5658.2	9.8	-
C	1990	7928.6	7.0	-
A	1995	11865.4	8.4	-
S	2000	17756.8	8.4	-
T				

* BASED ON DOLLAR VALUE.
\# SOURCE: BUREAU OF THE CENSUS. SA 305, FT 150, "U.S. GENERAL IMPORTS".

Figure IV-28B

U.S. WATERBORNE IMPORTS OF GAS
(Source: Reference [85])

Figure IV-28C indicates that the waterborne share of coal imports will increase through 1990. The implications of energy independence have complicated the forecasting of the waterborne portion of coal imports.



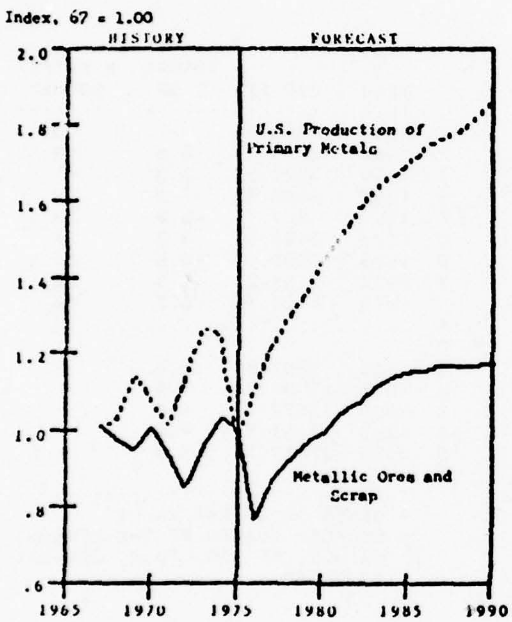
	YEAR	000 LT	ANNUAL % GR	% WATER-BORNE*
	1967	87.4	-	29
H#	1968	62.0	-29.1	22
I	1969	21.7	-64.9	9
S	1970	18.7	-13.9	12
T	1971	45.6	143.8	18
O	1972	62.4	36.6	29
R	1973	896.2	1337.2	83
Y	1974	4866.8	443.0	96
	1975	2290.8	-52.9	93
F				
O				
R	1980	3453.6	8.6	-
E	1985	6277.4	12.7	-
C	1990	9126.2	7.8	-
A	1995	14835.6	10.2	-
S	2000	24116.6	10.2	-
T				

* BASED ON VOLUME.
# SOURCE: BUREAU OF THE CENSUS, SA 305, FT 150, "U.S. GENERAL IMPORTS".

Figure IV-28C

U.S. WATERBORNE IMPORTS OF COAL AND COKE
(Source: Reference [85])

Figure IV-28D shows waterborne imports of metallic ores and scrap. The ores and scrap included are: iron ores and concentrates (73 percent), ores and concentrates of nonferrous base metals (26 percent), and nonferrous scrap (1 percent). Total imports of iron and steel scrap, silver and platinum, and thorium ores and concentrates comprise a negligible amount of the total. This is the second largest group of imported materials. No consistent trend in the movement of these commodities by water is apparent.



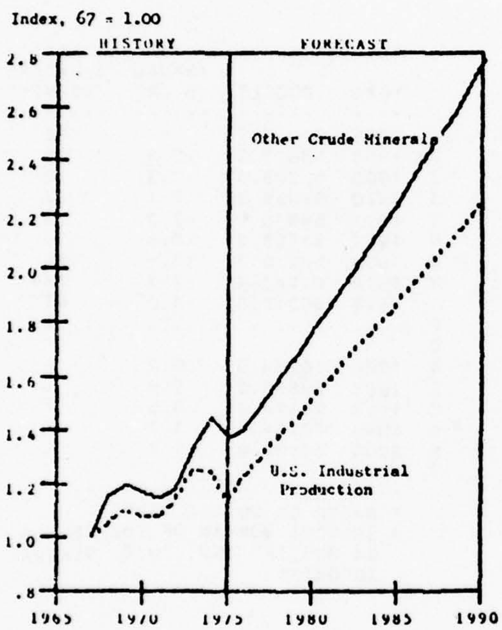
	YEAR	000 LT	ANNUAL % GR	% WATER-BORNE*
	1967	61018.7	-	83
H#	1968	58673.3	-3.8	80
I	1969	57305.8	-2.3	78
S	1970	61369.3	7.1	77
T	1971	56945.9	-7.2	78
O	1972	51495.6	-9.6	78
R	1973	58240.3	13.1	75
Y	1974	62743.4	7.7	74
	1975	60212.8	-4.0	81
F				
O				
R	1980	60704.5	0.2	-
E	1985	69856.3	2.8	-
C	1990	71614.9	0.5	-
A	1995	77784.7	1.7	-
S	2000	84486.2	1.7	-
T				

* BASED ON DOLLAR VALUE.
# SOURCE: BUREAU OF THE CENSUS, SA 305, FT 150, "U.S. GENERAL IMPORTS".

Figure IV-28D

U.S. WATERBORNE IMPORTS OF METALLIC ORES AND SCRAP
(Source: Reference [85])

Figure IV-28E treats the import category of miscellaneous crude minerals. This category includes crude fertilizers (3 percent), natural abrasives (2 percent), sulfur and unroasted iron pyrites (15 percent), and other crude minerals (80 percent). These commodities comprised 5.2 percent of the non-oil waterborne imports into the United States in 1975.



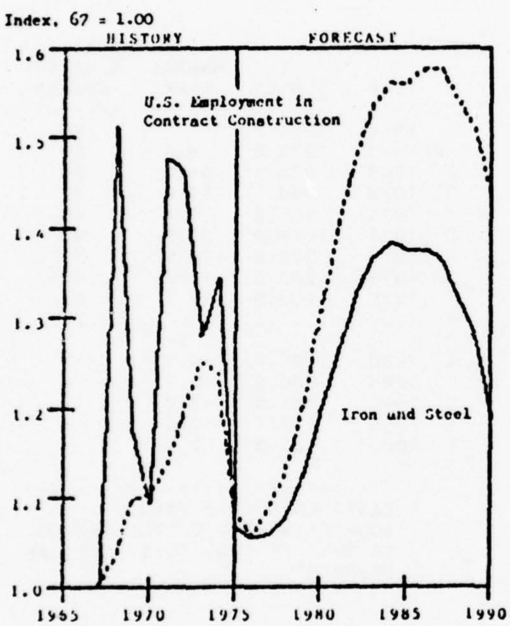
	YEAR	000 LT	ANNUAL % GR	% WATER-BORNE*
H#	1967	4933.9	-	40
I	1968	5689.1	15.3	42
S	1969	5877.3	3.3	41
T	1970	5685.4	-3.3	39
O	1971	5637.7	-0.8	38
R	1972	5822.0	3.3	34
Y	1973	6606.1	13.5	35
	1974	7151.2	8.3	38
	1975	6700.7	-6.3	46
F O R E	1980	8687.6	5.3	-
C	1985	11001.3	4.8	-
A	1990	13672.3	4.4	-
S	1995	17151.9	4.6	-
T	2000	21517.1	4.6	-

* BASED ON DOLLAR VALUE.
\# SOURCE: BUREAU OF THE CENSUS, SA 305, FT 150, "U.S. GENERAL IMPORTS".

Figure IV-28E

U.S. WATERBORNE IMPORTS OF MISCELLANEOUS CRUDE MINERALS
(Source: Reference [85])

Iron and steel imports accounted for 8.6 percent of the non-oil imports in 1975. Iron and steel plates and sheets comprised 23 percent of this import category, and assorted other finished and semifinished forms made up the remaining 77 percent. See Figure IV-28F.



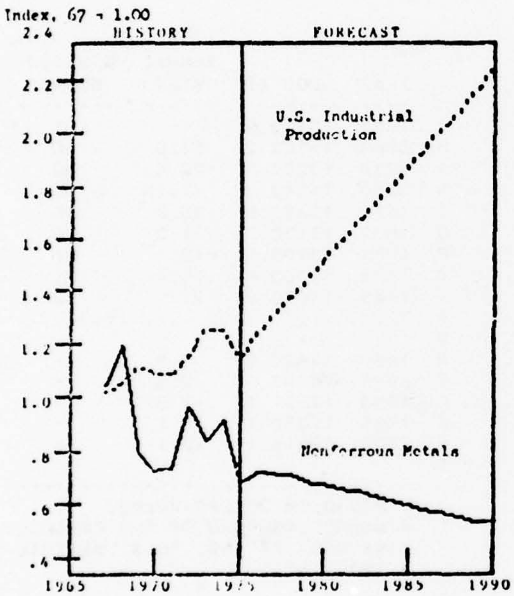
	YEAR	000 LT	ANNUAL % GR	% WATER-BORNE*
	1967	10413.9	-	91
H#	1968	15727.2	51.0	90
I	1969	12204.3	-22.4	90
S	1970	11343.3	-7.1	90
T	1971	15371.5	35.5	90
O	1972	15170.0	-1.3	90
R	1973	13288.1	-12.4	91
Y	1974	14000.6	5.4	91
	1975	11043.0	-21.1	92
F				
O				
R	1980	12426.2	2.4	-
E	1985	14257.9	2.8	-
C	1990	12321.7	-2.9	-
A	1995	12269.8	-0.1	-
S	2000	12218.1	-0.1	-
T				

* BASED ON DOLLAR VALUE.
\# SOURCE: BUREAU OF THE CENSUS. SA 305. FT 150. "U.S. GENERAL IMPORTS".

Figure IV-28F

U.S. WATERBORNE IMPORTS OF IRON AND STEEL
(Source: Reference [85])

The nonferrous metals (Figure IV-28G) group is composed of 30 percent copper and copper alloys, 26 percent aluminum and aluminum alloys, 24 percent zinc and zinc alloys, 7 percent tin and tin alloys, 5 percent lead and lead alloys, 4 percent base metals and alloys, and 3 percent nickel and nickel alloys. These commodities comprised 0.5 percent of the non-oil waterborne import volume in 1975. Overland shipments from Canada caused the 15-percent decline between 1967 and 1975.



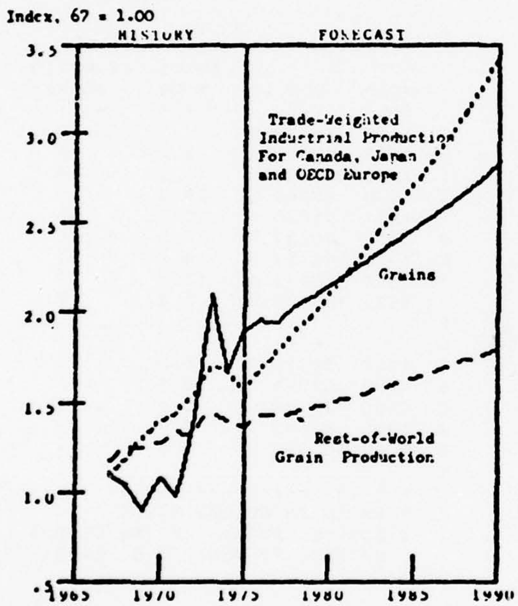
	YEAR	000 LT	ANNUAL % GR	% WATER-BORNE*
	1967	1089.2	-	58
H#	1968	1271.8	16.8	59
I	1969	830.1	-34.7	50
S	1970	750.1	-9.6	49
T	1971	765.8	2.1	45
O	1972	1018.2	33.0	47
R	1973	870.9	-14.5	45
Y	1974	960.3	10.3	48
	1975	703.5	-26.7	43
F				
O				
R	1980	695.6	-0.2	-
E	1985	606.5	-2.7	-
C	1990	541.5	-2.2	-
A	1995	477.7	-2.5	-
S	2000	421.5	-2.5	-
T				

* BASED ON DOLLAR VALUE.
\# SOURCE: BUREAU OF THE CENSUS. SA 305, FT 150, "U.S. GENERAL IMPORTS".

Figure IV-28G

U.S. WATERBORNE IMPORTS OF NONFERROUS METALS
(Source: Reference [85])

The exported commodity "grain" includes wheat (42 percent), unmilled cereals (3 percent), wheat flour (1 percent), cereals and flour preparations (1 percent), and general grains (53 percent). This commodity group made up 30 percent of the total U.S. exported tonnage in 1975. See Figure IV-28H.



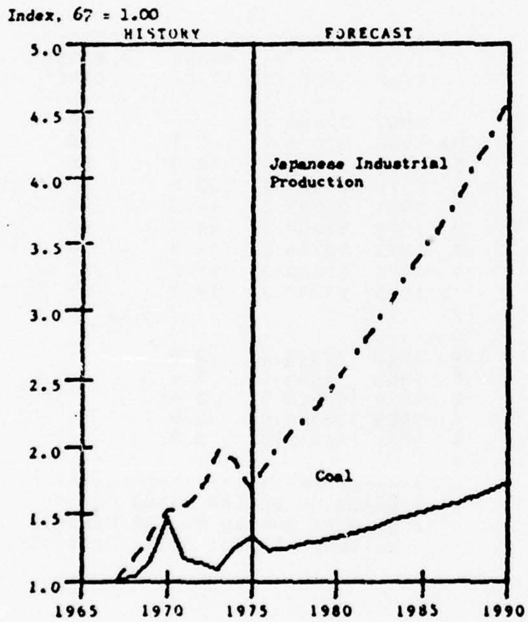
	YEAR	000 LT	ANNUAL % GR	% WATER-BORNE*
	1967	39960.7	-	98
H#	1968	37914.9	-5.1	98
I	1969	31897.4	-15.9	96
S	1970	39387.2	23.5	97
T	1971	35385.0	-10.2	98
O	1972	51204.8	44.7	98
R	1973	80356.6	56.9	98
Y	1974	62846.2	-21.8	97
	1975	71747.2	14.2	97
F				
O				
R	1980	82448.3	2.8	-
E	1985	95066.6	2.9	-
C	1990	109683.5	2.9	-
A	1995	126509.0	2.9	-
S	2000	145915.5	2.9	-
T				

* BASED ON DOLLAR VALUE.
\# SOURCE: BUREAU OF THE CENSUS. SA 705. FT 450. "U.S. EXPORTS".

Figure IV-28H

U.S. WATERBORNE EXPORTS OF GRAINS
(Source: Reference [85])

Coal accounts for 24.5 percent of the total U.S. waterborne exports and is the second largest export. Japan and Canada receive 64 percent of the quantity exported. As world steel production increased in 1970, the producers stockpiled coal which led to a decline in shipments during 1971 to 1973 as the steel market declined. A threatened U.S. miners strike and increased oil prices stimulated the sharp increase in 1974. See Figure IV-28I.



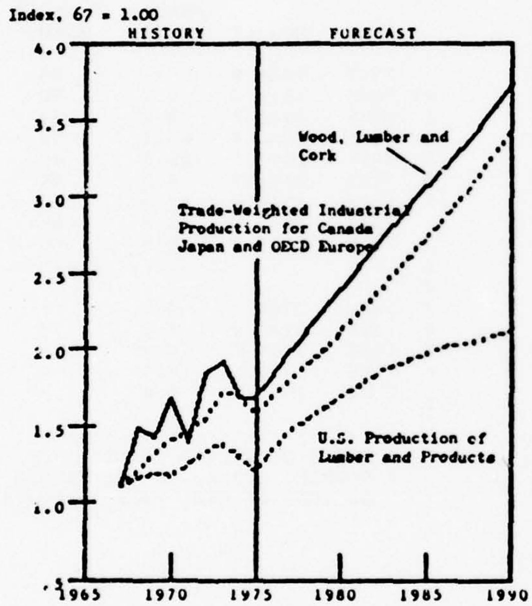
	YEAR	000 LT	ANNUAL % GR	% WATER-BORNE*
	1967	44499.9	-	95
H#	1968	45495.6	2.2	95
I	1969	50896.5	11.9	94
S	1970	65240.5	28.2	97
T	1971	51630.1	-20.9	96
O	1972	50667.7	-1.9	96
R	1973	48192.8	-4.9	97
Y	1974	55442.4	15.0	97
	1975	58898.2	6.2	97
F O				
R	1980	58829.2	-0.0	-
E	1985	67041.8	2.6	-
C	1990	76738.1	2.7	-
A	1995	87643.7	2.7	-
S	2000	100099.0	2.7	-
T				

* BASED ON DOLLAR VALUE.
\# SOURCE: BUREAU OF THE CENSUS. SA 705, FT 450, 'U.S. EXPORTS".

Figure IV-28I

U.S. WATERBORNE EXPORTS OF COAL
(Source: Reference [85])

Japan received 87 percent of all U.S. exports of wood, lumber, and cork in 1975. Such shipments comprised 4.8 percent of the total number of tons of all commodities exported by the United States that year. Included in this grouping are 85 percent wood in the rough and 15 percent wood shaped or simply worked. Dock strikes in the United States resulted in declines in export tonnages in 1969 and 1971. See Figure IV-28J.



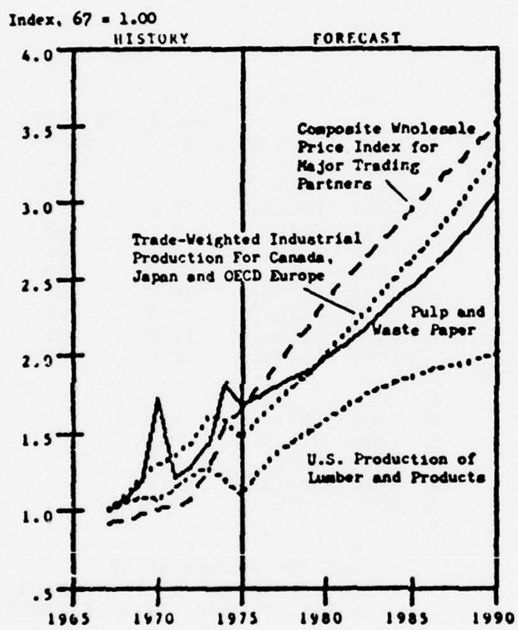
	YEAR	000 LT	ANNUAL % GR	% WATER-BORNE*
	1967	7320.2	-	78
H#	1968	10041.1	37.2	83
I	1969	9630.5	-4.1	83
S	1970	11523.8	19.7	86
T	1971	9450.4	-18.0	82
O	1972	12670.7	34.1	83
R	1973	13291.9	4.9	86
Y	1974	11564.8	-13.0	83
	1975	11495.0	-0.6	83
F				
O				
R	1980	16711.0	7.8	-
E	1985	21610.1	5.3	-
C	1990	26490.7	4.2	-
A	1995	33353.3	4.7	-
S	2000	41993.7	4.7	-
T				

* BASED ON DOLLAR VALUE.
\# SOURCE: BUREAU OF THE CENSUS. SA 705, FT 450, "U.S. EXPORTS".

Figure IV-28J

U.S. WATERBORNE EXPORTS OF WOOD AND LUMBER
(Source: Reference [85])

Pulps and waste paper made up 1.2 percent of the U.S. export tonnage in 1975. Countries lacking forest resources are expected to rely more heavily on the United States, Canada, and the U.S.S.R. for these commodities [85]. The importing countries are Japan, Italy, England, Germany, and France. See Figure IV-28K.



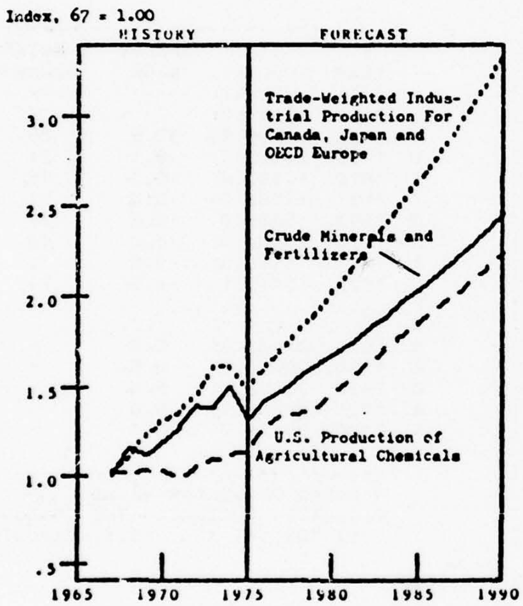
	YEAR	000 LT	ANNUAL % GR	% WATER-BORNE*
HISTORY#	1967	1686.8	-	94
	1968	1819.4	7.9	93
	1969	1989.9	9.4	92
	1970	2888.3	45.1	91
	1971	2053.1	-28.9	89
	1972	2151.7	4.8	90
	1973	2389.0	11.0	88
	1974	3087.8	29.2	86
	1975	2825.6	-8.5	89
FORECAST	1980	3356.1	3.5	-
	1985	4144.2	4.3	-
	1990	5151.7	4.4	-
	1995	6382.8	4.4	-
	2000	7908.0	4.4	-

* BASED ON DOLLAR VALUE.
\# SOURCE: BUREAU OF THE CENSUS. SA 705, FT 450, "U.S. EXPORTS".

Figure IV-28K

U.S. WATERBORNE EXPORTS OF PULPS AND WASTE PAPER
(Source: Reference [85])

Crude fertilizers and minerals commodity grouping made up 7.3 percent of U.S. waterborne export commodities in 1975. This commodity group includes crude fertilizers (55 percent), stone, sand and gravel (23 percent), other crude minerals (14 percent), and sulfur and crude iron pyrites (7 percent). Thirty-four percent of these commodities were exported to Canada. See Figure IV-28L.



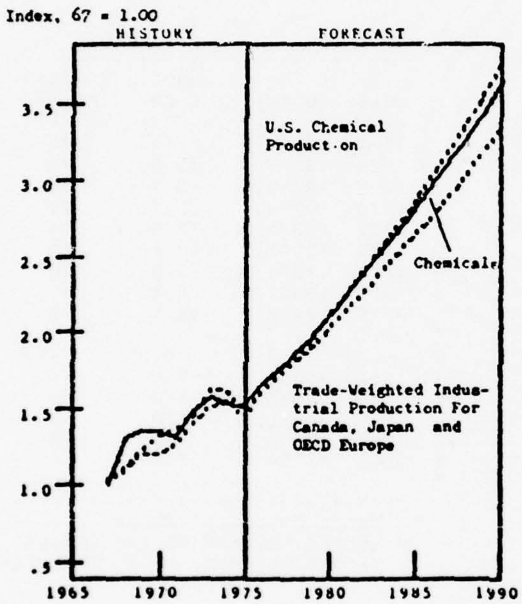
	YEAR	000 LT	ANNUAL % GR	% WATER-BORNE*
	1967	13290.5	-	72
H#	1968	15278.2	15.0	73
I	1969	14718.2	-3.7	72
S	1970	15764.7	7.1	72
T	1971	16842.0	6.8	71
O	1972	18541.5	10.1	70
R	1973	18271.4	-1.5	70
Y	1974	19887.7	8.8	77
	1975	17475.2	-12.1	79
F				
O				
R	1980	22268.3	5.0	-
E	1985	27073.2	4.0	-
C	1990	32610.0	3.8	-
A	1995	39462.3	3.9	-
S	2000	47754.6	3.9	-
T				

* BASED ON DOLLAR VALUE.
\# SOURCE: BUREAU OF THE CENSUS. SA 705, FT 450, "U.S. EXPORTS".

Figure IV-28L

U.S. WATERBORNE EXPORTS OF CRUDE FERTILIZERS AND MINERALS
(Source: Reference [85])

The export commodity chemicals, which includes 14 chemicals, accounted for 6.4 percent of total tonnage of U.S. waterborne exports in 1975. Organic chemicals and manufactured fertilizers comprise 58 percent of this commodity group. The present trend of negative annual growth is expected to reverse and result in an export volume of 63.4 million long tons of chemicals by 2000 (Figure IV-28M).



	YEAR	000 LT	ANNUAL % GR	% WATER-BORNE*
H#	1967	10159.7	-	74
I	1968	13300.9	30.9	75
S	1969	13712.0	3.1	71
T	1970	13682.4	-0.2	75
O	1971	13188.0	-3.6	71
R	1972	15005.8	13.8	67
Y	1973	15909.4	6.0	69
	1974	15490.0	-2.6	71
	1975	15412.1	-0.5	71
F				
O				
R	1980	21442.4	6.8	-
E	1985	28368.5	5.8	-
C	1990	36878.9	5.4	-
A	1995	48364.9	5.6	-
S	2000	63428.2	5.6	-
T				

* BASED ON DOLLAR VALUE.
\# SOURCE: BUREAU OF THE CENSUS. SA 705, FT 450, "U.S. EXPORTS".

Figure IV-28M

U.S. WATERBORNE EXPORTS OF CHEMICALS
(Source: Reference [85])

The number of vessels in the U.S. flag merchant marine is shown in Table IV-49.

Table IV-49.

U.S.-FLAG OCEANGOING MERCHANT FLEET AS OF APRIL 30, 1976[1]
(tonnage in thousands of deadweight tons)
(Source: Reference [80])

	Totals		Combination Passenger/Cargo		Freighters		Tankers	
	Private	USMA[2]	Private	USMA	Private	USMA	Private	USMA
Active	531	12	6	0	299	11	266	1
Total	543		6		310		227	
Tonnage	13,906	108	50	0	5,223	104	8,633	4
Total	14,014		50		5,327		8,637	
Inactive	44	257	0	53	22	191	22	13
Total	301		53		213		35	
Tonnage	1,215	2,458	0	334	261	1,940	954	184
Total	3,673		334		2,201		1,138	
TOTAL	575	269	6	53	321	202	248	14
Total	844		59		523		262	
Tonnage	15,121	2,566	50	344	5,484	2,044	9,587	183
Total	17,687		384		7,528		9,775	

[1]Excludes vessels operating exclusively on the inland waterways, Great Lakes, and those owned by the U.S. Army and U.S. Navy, and special types such as cable ships, tugs etc. [2]Owned by the U.S. Maritime Administration.

Over 90 percent of imports and exports for the United States is handled by foreign vessels. As of December 31, 1974, U.S. owners had 706 merchant ships under foreign registry. Changes in the types of vessels in the trade have been noted in larger crude oil carriers, barge-carrying vessels, and container carriers. A 1976 study by the U.S. Maritime Administration identified characteristics of new U.S. vessels, as shown in Table IV-50.

Table IV-50

SIZE AND SPEED OF U.S. VESSELS
(Source: Reference [80])

Vessel Type	DWT	Speed
Container	22,500	22.5
Barge carrier (LASH)	40,000	22
Roll-on/Roll-off(Ro-Ro)	18,000	23
Neobulk	15,000	15
Heavy lift	5,000	11.5
Dry bulk	30,000	16
Tanker: Domestic	53,000	15.5
Alaska	118,000	15.5
Virgin Islands	35,000	15.5
Liquified natural gas (LNG)	125,000 – 165,000 m^3	17

Source: U.S. Maritime Administration.

The Maritime Administration has projected the composition of the U.S. deepwater fleet as shown in Table IV-51. These vessels can be used for domestic ocean as well as for international trades.

Table IV-51

PROJECTIONS OF U.S. OCEANGOING FLEET
(Source: Reference [80])

Type Vessel	1975 (Actual)	1980	1985
Breakbulk	134	127	101
Containership	109	106	133
Part Container	21	21	16
Combination pass/cargo	6	4	4
Barge carrier	23	27	41
Roll-on/Roll-off (Ro-Ro)	13	24	39
Neobulk	0	0	6
Heavy lift	0	1	4
Dry bulk	17	6	21
Tanker	234	204	177
Specialized tanker	18	12	20
Liquified natural gas (LNG)	0	24	36
Total	575	556	598

Source: U.S. Maritime Administration.

3. *Impact on the Coast Guard*

The Coast Guard's response to increased waterborne traffic can take a number of forms. An example of this is the need to inspect more vessels in drydock or observe more loadings and unloadings as more vessels become operational Another type of response might be made in a discrete fashion. For example, the growth of traffic within a specific port area may require a major improvement in vessel traffic services at that port. The availability of navigational aids or even communications services may be insufficient to provide the required level of safety in that waterway. The continuous response will be made initially through reallocation of resources at the local level and eventually through realignments between units at the District and Headquarters level. Ultimately, additional resources from Headquarters may be required. The discrete response will require funding at the Headquarters level with planning assistance locally and in the District.

This mechanism can operate in the whole range of Coast Guard programs that deal with commercial navigation. These include: Commercial Vessel Safety (CVS), Marine Environmental Protection (MEP); Port Safety and Security (PSS); Short-Range Aids to Navigation (AtoN); Radio Aids to Navigation (RA); Bridge Administration (BA); Ice Operations (IO); and Search and Rescue (SAR).

Knowing what commodities will be carried is important to determine potential impacts on the Coast Guard. For example, increases in barge carriage of coal have impact on the number of towboat operators and the amount of traffic congestion. But increases in barge carriage of petroleum have wider impact because it will significantly affect the number of vessels to be inspected and visited.

4. *Conclusions*

- Water transportation of mineral, agricultural, and energy commodities will expand in inland, Great Lakes, domestic ocean, and international ocean trades.

- Coast Guard impacts will be felt in needs to make marginal adjustments or significant increases to available resources of manpower and facilities to provide transportation facilitation services to maritime commerce.

- *Programs that will be affected* include Commercial Vessel Safety, Marine Environmental Protection, Port Safety and Security, Short-Range Aids to Navigation, Radio Aids to Navigation, Bridge Administration, Ice Operations, and Search and Rescue.

Chapter V

FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

This chapter is a summary of the results of an analysis of Coast Guard critical materials problems and opportunities. The results are presented as a series of findings of facts and conclusions grouped under specific topics, namely:

A. Critical Materials—General
B. The Materials Community
C. Department of Defense Critical Materials Activities
D. Coast Guard Critical Materials Activities
E. Specifications and Standards
F. Classification of Materials
G. Selection of Criteria To Identify Potential Critical Materials
H. Ranking of Materials Critical to the Coast Guard
I. Special Causes of Coast Guard Shortages
J. Consumption Impacts
K. Programmatic Impacts

Each finding or conclusion is referenced to a specific section in the main body of the report or to an appendix where the rationale and basis for the finding are discussed. Recommendations are presented at the end of each group of findings, when appropriate.

A. CRITICAL MATERIALS—GENERAL

- There has been a national commitment developing since World War II to develop plans and stockpiles of potential critical materials to ensure that all military mobilization and essential civilian needs are satisfied. (I.B.)

- The 1973-1974 energy embargo, environmental concerns, economic issues, political alignments, and technological changes have all brought materials shortages to the public eye. (I.B.)

- Materials availability should be considered within the context of a materials life cycle with four interrelated phases: *supply, conversion, use,* and *disposal.* (II.A.2.)

- *Materials availability, energy,* and the *environment* form an intimately interacting trichotomy. (II.A.2.)

● The supply of critical materials can decrease due to a number of causes such as: physical scarcity; domestic business cycle; domestic inflation; labor disruptions; national foreign policy; environmental and energy restrictions; cost of capital for new facilities; tax and investment incentives; shortage mentalities; international trade barriers; cartelized control of foreign sources; international politics; and numerous other domestic and international social/political/economic factors. (II.A.3.)

● The supply of critical materials can increase through actions such as: stockpiling; technological improvements; expansion of domestic production; incentives for exploiting lower grade ores; international political approaches; trade agreements; and general improvement in the world social/political/economic condition. (II.A.3.)

● The demand for critical materials can decrease through actions such as: substitution with a more available material; relaxation of performance requirements to permit acceptable alternatives; redesign; control of specifications; increasing durability; recovery of waste products; conservation; and rehabilitation. (II.A.4.)

----*RECOMMENDATION:* That the Coast Guard expand its interest in critical materials issues and acquaint its personnel with opportunities to extend supply and decrease demand for scarce materials.

B. THE MATERIALS COMMUNITY

● An extensive materials community presently exists in the Federal Government, industry, and academia that continually collects and analyzes information on the present and projected need for and availability of materials, for the purpose of identifying critical materials problems and potential solutions as early as possible. (II.B.1.)

● The active members of the materials establishment within the Government have generally been unaware of Coast Guard programs and facilities that could be impacted by critical materials shortages. These analysts and policymakers in the Department of Defense (DOD), Department of the Interior (DOI), Department of Commerce (DOC), and General Services Administration (GSA) have had substantial impact in the past in forestalling the unfavorable impacts of anticipated critical materials shortages in their own organizations. They have not been tuned in to Coast Guard materials-related problems. (II.B.1.)

● There are hundreds of Government employees at work all over the country collecting data, analyzing trends, preparing publications, communicating information, determining policies, establishing an analytical base for stockpiling decisions, and keeping each other informed about potential future critical materials problems. Those who were contacted were most willing to receive our inquiries and appeared to be very receptive to cooperating with the Coast Guard in any steps that it may take to become active in critical materials issues. (I.D.)

----*RECOMMENDATION:* That the Coast Guard obtain early warning of critical materials problems and opportunities by keeping in close contact with the materials establishment in the Government, and with the materials community in general, thus obtaining information as early as possible as to what materials problems are expected.

C. DEPARTMENT OF DEFENSE (DOD) CRITICAL MATERIALS ACTIVITIES

● The DOD has developed an effective procedure to use research, development, engineering, and logistics sources to prevent potential materials shortages from having major consumption impacts on the military services. (I.D.)

● The DOD has been able to minimize some impacts of environmental regulations on the military services through advance awareness of potential problems and negotiations with regulatory agencies. (II.B.2.)

● The Coast Guard usage of materials has many similarities with the Department of Defense usage. (II.D.2.)

● The Coast Guard is part of the Defense Materials System (DMS) and the Defense Priorities System (DPS) and can assign priorities to suppliers of scarce materials. This can be effectively used if information is available prior to the development of shortages. (II.B.)

----*RECOMMENDATION:* That the Coast Guard should pattern elements of future critical materials activities on DOD procedures and should use available information from the DOD system and from other governmental sources for Coast Guard critical materials intelligence gathering.

D. COAST GUARD CRITICAL MATERIALS ACTIVITIES

- While there are Coast Guard personnel concerned about materials shortages, there has been a relatively low level of awareness of potential critical materials problems within the Coast Guard. There have been isolated cases where potential problems have been anticipated and then defused through advance procurement or redesign activities. In general, however, there has been no deliberate, systematic collection of readily available materials information from outside of the Service, except on an informal ad hoc basis. (II.B.1.)

- Coast Guard sponsorship of this study indicates a growing sensitivity to critical materials problems and opportunities. One of the benefits of this study was that it provided an opportunity to communicate to Coast Guard personnel a heightened awareness about national critical materials problems, other agencies' materials information and early warning systems, industrial activities with materials, and possible responses by the maritime industry to critical materials problems. (II.B.1.)

----*RECOMMENDATION:* That the Coast Guard should establish and maintain an awareness of the impacts of those materials that are now important, or that can be expected to become important, to the proper fulfillment of the Service's mission. It needs a mechanism for identifying, classifying, assessing, substituting, and responding to potential critical materials problems and opportunities.

- A major benefit of having an ongoing critical materials system will accrue to the Coast Guard when the economy heats up and production bottlenecks develop, as in the years 1973-1974. The personnel associated with the established critical materials systems can then be mobilized readily to identify problem areas and to offer alternative solutions to decision-makers. The economic benefits will be very large during those peak demand periods when shortages can cause excessive waste through hasty substitution or in unused facilities. (II.B.2.)

- A heightened awareness of critical materials problems can produce economic gains to the Coast Guard through advance planning by inventorying potentially scarce materials, substituting with more available materials, and designing for longer life, increasing definitive specification control, and utilizing materials conservation techniques. More effective and efficient overall utilization of materials would be the net result. (II.B.2.)

● Another benefit can devolve from other Federal agencies' materials experts having better knowledge of the Coast Guard's activities and capabilities. There may be opportunities where a shortage in another agency can be prevented or alleviated by that agency borrowing Coast Guard equipment or material, or vice versa. (II.B.2.)

----*RECOMMENDATION:* That the Coast Guard should integrate a new materials information system into the ongoing Coast Guard planning system, which will minimize the need for additional staff resources.

● The Coast Guard critical materials system (see Figure V-1) should incorporate the following four basic functional elements:

- An information center for monitoring, obtaining, collating, evaluating, and distributing pertinent information from many sources (*Critical Materials Information Center*).
- A capability for in-depth analysis and assessment of materials information to determine whether there is a potential threat or opportunity for Coast Guard activities and missions.
- A process of decisionmaking to determine what action, if any, should be taken, and what long-range plans should be revised or introduced.
- The implementation of decisions (including feedbacks to previous phases). (III.A.)

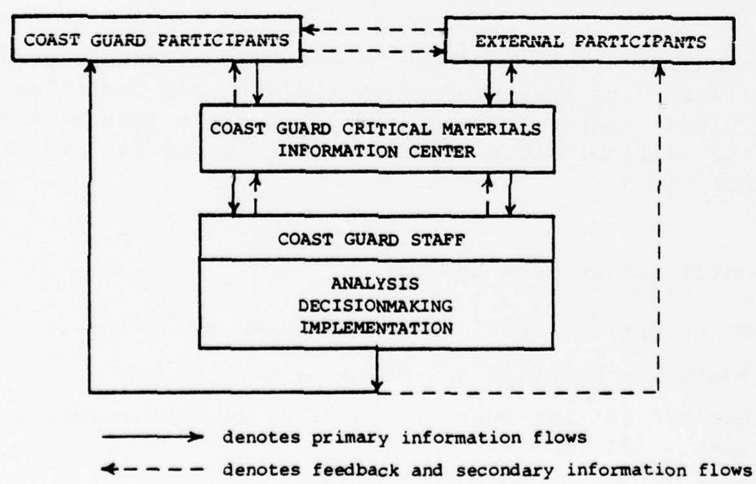


Figure V-1

COAST GUARD CRITICAL MATERIALS INFORMATION SYSTEM

----*RECOMMENDATION:* That the Coast Guard designate a recognizable staff element as the focal point for critical materials activities.

----*RECOMMENDATION:* That the *Critical Materials Information Center* be responsible for:

Δ Collecting and reviewing data.

Δ Interfacing with the materials community.

Δ Representing the Coast Guard for interagency materials activities.

Δ Monitoring regulatory activities.

Δ Evaluating materials data.

Δ Assisting in planning in-depth assessments.

Δ Disseminating internal information.

----*RECOMMENDATION:* That the Coast Guard should make full use of existing sources of national and world data and *should not* develop an in-house capability for assessing national and international economic and political indicators.

● Each Coast Guard unit and functional staff element is best informed about its own critical needs and applications, both existing and potential. It is usually in the best position to evaluate the implications of threatened shortages. (III.C.)

----*RECOMMENDATION:* That in-depth assessments of potential critical materials impacts be performed by the affected Coast Guard units or functional staffs. The Critical Materials Information Center should be available to provide information and its own preliminary analyses.

● The decision process should:

- Identify options for action (including no action).
- Evaluate the benefits and costs of each option.
- Select the optimum course of action, or combination of actions. (III.D.)

- Options for action include:
  - Material substitution.
  - Redesign for material elimination, material usage reduction, or longer life.
  - Conservation through scrap reduction, improved manufacturing processes, rework, repair, recycling.
  - Respecification to accept lower performance characteristics.
  - Substitution of a device, technique, or equipment to perform the same function.
  - Stockpiling. (II.A. and III.D.)

- The effectiveness of a critical materials system will be heightened through integration into the normal decisionmaking and functional processes of the Coast Guard. This will ease the introduction of a materials consciousness throughout the Service. (III.D.)

----*RECOMMENDATION:* That the Coast Guard treat critical materials decisions within the normal context of organizational decisionmaking at all levels of command.

----*RECOMMENDATION:* That the effects of Coast Guard actions in dealing with critical materials issues should be monitored, reviewed, and used to judge how effective were the prior system functions of data collection, evaluation, decision, and execution. Information should be fed back to the Critical Materials Information Center at all stages of the process.

E. SPECIFICATIONS AND STANDARDS

- Use of nonstandard specifications and parts can lead to availability problems and almost always to increased cost. The availability problem can affect, of course, initial procurement, but may be even more serious when operating units attempt to repair or replace a malfunctioning piece of nonstandard equipment years later. (II.C.)

- Design engineers often overlook questions of producibility, availability, repairability, replaceability, and cost when designing for maximum performance. (II.C.)

- Functional performance requirements rather than specific and restrictive design requirements can increase engineering flexibility. (II.C.)

----*RECOMMENDATION:* That the Coast Guard publicize internally the desirability of using specifications and standards that are as broad as deemed safe, so that the designer and materials engineer may have the flexibility to use suitable available alternates if the original material or equipment becomes scarce.

F. *CLASSIFICATION OF MATERIALS*

● A classification system is useful as a systematic base for analyzing materials needs and as a comprehensive means for conveying and obtaining related information. Through the system, the Coast Guard can identify the precise categories of materials in which it is interested. (II.D.)

----*RECOMMENDATION:* That the Coast Guard use the Federal Supply Classification System, which is the numerical identification basis for the entire Coast Guard logistics system, for Coast Guard critical materials purposes.

G. *SELECTION CRITERIA TO IDENTIFY POTENTIAL CRITICAL MATERIALS*

● Eight criteria were developed to evaluate various elements of criticality in a quantitative fashion:

- *Import Dependence*
- *Foreign Vulnerability*
- *Regulatory Sensitivity*
- *Monopolistic Dependence*
- *Limited Alternatives*
- *Technological Necessity*
- *Coast Guard Technological Significance*
- *National Technological Insignificance*

H. *RANKING OF MATERIALS CRITICAL TO THE COAST GUARD*

- By applying the evaluation criteria, the following list of materials critical to the Coast Guard is stratified into three levels of criticality:

HIGH	Beryllium Petrochemicals Petroleum
MIDDLE	Aluminum/aluminum alloys Antimony Asbestos Bismuth Cable, submarine Cadmium Chromium Cobalt Columbium Diamond, industrial Electron tubes Jewel bearings Lead Manganese Mercury Mica Natural gas Nickel Paper Rubber, natural Selenium Silver Tin Titanium Tungsten Vanadium Zinc
LOW	Chlorofluorocarbon compounds Copper Cordage fibers Down feathers Lithium Molybdenum Quartz crystals Thorium Water, potable

(II.E.5.)

I. SPECIAL CAUSES OF COAST GUARD SHORTAGES

- While the normal Coast Guard logistics system functions very well, some potential shortage problems are not being systematically addressed. These problems can be caused by technological obsolescence, uneconomic ordering quantities, and inadequate numbers of available domestic suppliers. (I.D.)

- A problem has been identified concerning the relationship between technological obsolescence and maintenance of logistical support for aging mechanical and electronic systems. Technological developments which encourage suppliers to shift to newer markets and other production techniques cause another form of critical materials problem. (I.D.)

- The major impact in the Coast Guard, caused by maintaining obsolete equipment, will be in electronics systems. The increasing use of advanced solid-state technology will result in the limited availability of certain components required by aging Coast Guard systems. This will cause excessive downtime in electronic systems. (Appendix F.)

- Some Coast Guard procurements are so small in dollar value or in the size of production run that there is little incentive for commercial firms to compete in supplying the product. This results in numerous single-source procurements. (I.D.)

- One cause of diminishing sources of domestic suppliers for aging Coast Guard systems is due to the imposition of new and expensive environmental, health, and safety regulations on suppliers. (I.B.)

----*RECOMMENDATION:* That the Coast Guard should undertake an economic analysis of life cycle costs of various aging systems to develop parameters and indicators that would provide guidance for determining when maintenance of an existing system will become so inefficient as to justify redesign, replacement, or removal.

- The Coast Guard can have an impact on proposed regulatory restrictions if they make their transitional needs known directly to the regulatory agency and via the Department of Defense. (III.B.)

----*RECOMMENDATION:* That the Coast Guard insure that recognized problems from impending or existing environmental, health, or safety regulatory constraints on the Coast Guard logistics chain are transmitted to the appropriate agencies to allow sufficient lead time for implementation with minimum problems for the Coast Guard.

J. *CONSUMPTION IMPACTS*

1. *General*

- Unanticipated shortages of necessary materiel can interfere with routine Coast Guard operations, maintenance, and construction programs. These shortages can become severely disruptive to the Coast Guard when they directly impact the logistics chain. They can also result in significant cost increases. (II.B.)

- Some material shortages may not be critical to the nation as a whole, but can be important to the Coast Guard as a major consumer of that material. (II.B.)

- Although temporary shortages of materials used by the Coast Guard have occurred in the past, no shortages where found that have had significant direct impact on Coast Guard operations. (IV.)

----*RECOMMENDATION:* That the Coast Guard should be alert to identify potential critical materials shortages that may have direct impacts on Coast Guard operations in the future.

- Case studies of the materials and products shown below resulted in a number of findings of facts and conclusions:

	CONSUMPTION IMPACTS
IN-DEPTH CASE STUDIES	Cadmium Mercury Jewel Bearings Icebreaker Propellers Paper
SUMMARY CASE STUDIES	Buoy Chain, 1$\frac{1}{4}$" and 1$\frac{1}{2}$" Electron Tubes Submarine Cables Batteries Halogenated Fluorocarbons Cordage Fibers

(IV., Appendix F.)

2. In-Depth Case Studies

a. Cadmium

- Cadmium is a critical material for the Coast Guard. Its availability is somewhat vulnerable due to a high level of import dependence and to a high susceptibility to regulatory control by the EPA. (IV.A.)

- Coast Guard utilization of cadmium is in proportion to DOD use in plating, pigments, stabilizers, batteries, and alloys. There is no Coast Guard-peculiar use. (IV.A.)

- No indications of past shortages of cadmium were identified during this study. Cadmium is presently stockpiled, and resources should last well beyond the year 2000. (IV.A.)

- If EPA regulations reduce the use of cadmium, there are a number of substitutes available for many but not all of its uses. (IV.A.)

b. Mercury

- Mercury is a critical material for the Coast Guard. It is somewhat vulnerable to foreign dependence and more vulnerable to environmental regulation. (IV.B.)

- Coast Guard usage of mercury is similar to U.S. domestic use, for electrical applications, instruments, dental supplies, pharmaceuticals, and preservatives and toxicants in paint. There is no Coast Guard-peculiar use. (IV.B.)

- No indications of past shortages of mercury were identified during this study. Mercury is presently stockpiled and supplies are adequate. (IV.B.)

- EPA regulations have induced shifts away from the use of mercury. There are substitutes available for each use. (IV.B.)

c. Jewel Bearings

- Jewel bearings are critical for the Coast Guard because of foreign dependence. (IV.C.)

- Shortages were noted during World War II when European, primarily Swiss, supplies were cut off. (IV.C.)

● Coast Guard utilization of jewel bearings is limited to precision instruments and timekeeping devices. There is no Coast Guard-peculiar use. (IV.C.)

● The Federal Government owns the only domestic factory for jewel bearings. Jewel bearings are stockpiled. (IV.C.)

● Most applications for jewel bearings are being replaced with light-emitting diodes, liquid crystal displays, timepieces without mechanical movements, improved metal bearings, and solid-state electronic instruments with digital readouts. (IV.C.)

d. Icebreaker Propellers

● Propellers for icebreakers are not easily procured. There are a limited number of suppliers due to the reluctance of vendors to deal with exacting Coast Guard Military Specifications, uneconomical order sizes, difficulties in casting and machining, and new environmental requirements on foundries. (IV.D.)

● Long lead times for procurements have been experienced, although no actual shortages have occurred. (IV.D.)

● The availability of the component materials for the propeller castings will not be a problem for the Coast Guard. (IV.D.)

● There are sufficient spare propellers existing for immediate expected needs. The Ships Inventory Control Point (SICP) is investigating lead time, inventories, and stock identification. (IV.D.)

e. Paper

● Paper is a critical material for the Coast Guard. Paper forms were in short supply during the national paper shortage of 1973-1974. (IV.E.)

● There are no practical, economic substitutes for paper. (IV.E.)

● Stockpiling of paper or paper forms was a contributing factor in the 1973-1974 shortages and should be discouraged. Timely, accurate ordering of paper products to fill actual demands and the recycling of wastepaper will assist in dealing with potential problems in availability. (IV.E.)

3. *Summary Case Studies*

● The Coast Guard is the primary domestic consumer of *1¼" and 1½" welded buoy chain*. One order is placed quarterly for delivery from a foreign source to all Districts. There is a limited amount of reserve stocks at Coast Guard facilities. Foreign deliveries are made regularly and at costs much lower than domestic suppliers would charge. Several U.S. companies currently have the technology and resources to produce the chain, but the low delivery price of foreign sources eliminates these U.S. companies from effective competition. (Appendix F.)

● The Coast Guard presently procures *electron tubes* for LORAN A and C transmitters from a sole-source supplier. Since technology advances quite rapidly, other manufacturers find it unprofitable to continue to make obsolete components for aging equipment. Many additional types of Coast Guard-used tubes and other electronic components could fall into this category during the next few years, as the electronics industry moves further into advanced solid-state materials. (Appendix F.)

● At present, the Coast Guard procures *submarine power and communication cables* from General Electric, Inc. Several firms have the capability to produce both types of cables, but the number of such firms is decreasing. Currently, General Electric is the sole source. (Appendix F.)

● Problems in *battery* supplies and usage could result from environmental constraints, diminishing manufacturing facilities, and shortages of critical materials used in manufacturing. The primary batteries used by the Coast Guard are the zinc-air cell type. The manufacturing sources of these batteries have decreased in the past few years. Environmental restrictions on manufacturing processes, plant emissions, and mercury may further curtail production. The secondary batteries used in aircraft and helicopters are nickel-cadmium cells, with the exception of the Grumman Albatross (HUF1G) and the C130 which still use lead-acid cells. Secondary battery production is not expected to be affected by diminishing manufacturing sources. (Appendix F.)

● The Environmental Protection Agency has proposed a ban on fully *halogenated chlorofluoroalkane propellants*, commonly called *fluorocarbons*, under the Toxic Substances Control Act. These substances are used in the Coast Guard as electronic and avionic cleaning compounds, refrigerants, fire extinguishers, aircraft suface cleaning compounds, and spray lubricants. As a result of certain exemptive provisions within the Toxic Substances Control Act and the prompt action of personnel of the Office of the Secretary of Defense, essential uses of fluorocarbons within the DOD are being allowed to continue while substitutes are under development. The Coast Guard use of such products is quite small compared to DOD usage. Coast Guard facilities have also taken steps designed to limit, or eliminate entirely, the use of such compounds. (Appendix F.)

• The United States procures all of its *natural cordage fibers* and *rope* from foreign sources. These fibers are currently used for a variety of products in the Coast Guard, such as: mooring lines, fenders, cross-deck lines on buoy tenders, etc. The national supply of these items and the basic fibers could be interrupted by an Asian war. The most available substitute for natural cordage fiber is nylon. There are, however, some minor problems using nylon in some applications, such as cross-deck lines, due to its greater elasticity. As of 1974, there were 138 million pounds of abaca and sisal cordage fibers in the national stockpile. This is being reduced because DOD is shifting to synthetic fibers. (Appendix F.)

K. PROGRAMMATIC IMPACTS

1. General

• Critical materials shortages can have indirect impacts on the Coast Guard when they act on the various constituencies that are served by the Coast Guard. This can result in unpredictable and deleterious effects on the Coast Guard's programs unless there is contingency planning for accommodating the changes resulting from critical materials shortages. (II.B.)

• A new material technology such as ferrocement vessels can give an early signal for a new training requirement for Marine Safety personnel. Floating offshore oil and gas extraction facilities and attendant offshore production concerned with energy sources will elicit new responses in the Search and Rescue, Short-Range Aids to Navigation, Merchant Marine Safety, Enforcement of Laws and Treaties, Port Safety and Security, and Marine Environmental Protection programs. Such advance notice can reduce regulatory lag within the Coast Guard and permit faster responses to the needs of the Service's constituents. (II.B.)

• Critical materials impacts on Coast Guard programs are derived from increasing worldwide consumption of energy, minerals, food, and freshwater. (IV.)

• National critical materials have had indirect impact on Coast Guard programs in the past (e.g., the increase in marine transportation of oil and the subsequent need for additional Coast Guard safety and environmental protection efforts). A number of new marine technologies and systems that are expected to grow out of U.S. materials shortages may have other implications for Coast Guard programs. (IV.)

----*RECOMMENDATION:* That the Coast Guard should recognize that early warnings of new technologies, services, construction, and other aspects of the maritime industry and other Coast Guard constituencies that are related to shortages of critical materials can assist planning for future resource needs and reduce regulatory lag by the Coast Guard.

• Case studies below resulted in a number of findings of facts and conclusions:

	PROGRAMMATIC IMPACTS
IN-DEPTH CASE STUDIES	Ferrocement and Prestressed Concrete Mineral, Agricultural, and Energy Commodity Movements
SUMMARY CASE STUDIES	Ocean Mining Ocean Thermal Energy Conversion Photochemical Energy Conversion Wave, Tidal, Ocean Current, Salinity Gradient and Hydropower Energy Conversion Floating Nuclear Power Plants Aquaculture Offshore Oil and Gas Exploitation Freshwater

(IV., Appendix F.)

2. *In-Depth Case Studies*

a. *Ferrocement and Prestressed Concrete*

• Ferrocement is increasingly being used for the construction of recreational and commercial boats due to its advantages of low capital investment for facilities, low-cost and readily available materials, low-skill labor requirements, ease of fabrication and repair, low maintenance, and fire resistance. (IV.F.)

• Prestressed concrete is being used increasingly for a marine construction material due to its low initial and maintenance costs, reduced need for drydocking and inspection, fire resistance, and ability to sustain cyclical loading and fatigue. (IV.F.)

• Use of ferrocement and prestressed concrete requires new expertise for designers, fabricators, operators, and inspectors. (IV.F.)

• Impacts of the use of these materials will be felt in the Coast Guard on Commercial Vessel Safety, Recreational Boating Safety, Port Safety and Security, Marine Environmental Protection, and Search and Rescue programs. (IV.F.)

b. Mineral, Agricultural, and Energy Commodity Movements

• Water transportation of mineral, agricultural, and energy commodities will expand in inland, Great Lakes, domestic ocean, and international ocean trades. (IV.G.)

• Coast Guard impacts will be felt in needs to make marginal adjustments or significant increases to available resources of manpower and facilities to provide transportation facilitation services to maritime commerce. (IV.G.)

• Programs that will be affected include Commercial Vessel Safety, Marine Environmental Protection, Port Safety and Security, Short-Range Aids to Navigation, Radio Aids to Navigation, Bridge Administration, Ice Operations, and Search and Rescue. (IV.G.)

3. Summary Case Studies

• *Mining of ocean floor manganese nodules* is technically feasible. Resolution of seabed legal status through Law of the Sea treaties or unilateral U.S. action is considered necessary before commercial extraction will begin. As worldwide demand for hard minerals continues to increase, the ocean mining industry will become economically viable. (Appendix F.)

• There could be from 250 to 300 *ocean thermal energy conversion* plants operating offshore by the year 2000. Of these, approximately 20 percent would be bottom-moored near the U.S. coast and the remainder would be free-floating on the ocean. Both designs would have crews of approximately 30 members living onboard. The moored electric plants could have high-voltage submarine cables connected to shore. The moored product and the free-floating plants would require tankers and dry bulk carriers to move raw materials and products such as ammonia, aluminum, steel, chlorine, potash, magnesium, ethylene, vinyl chloride, polyethylene, ethylene oxide, and caustic soda. Surface and air logistics support would be required by both designs for supplies, crew changes, and maintenance. (Appendix F.)

• *Photochemical energy conversion* involves methods designed to convert renewable resources into liquid and gaseous fuels, electric energy, and petrochemical substitutes. The three aquatic resource areas currently being developed are: freshwater systems, open-ocean systems, and shoreline-saltwater brackish water systems. General Electric plans to have approximately 1,000 acres of kelp growing by the mid-1980's. Commercial farms could be in operation by 1990. They could be located from 25 to 100 miles from the coast. The farm's structure is from 40 to 60 feet below the surface, and the supporting buoys involved would be approximately 8 to 10 feet in diameter. Freighters and cryogenic tankers

may be required to move products from the farm sites to potential markets. Surface and air logistics support will be required for routine maintenance, supply deliveries, and crew rotations. LNG ships may also be utilized to transport SNG to terminals ashore. (Appendix F.)

• One or more of a number of water-based, fuel-free electrical sources could come into commercial use by the year 2000. These are *wave, tidal, ocean current, salinity gradient, and hydropower energy.* Each of the sources of energy listed has had several concepts proposed to convert that energy into electricity or into a product that can produce electrical power. In addition to ocean thermal energy described above, salinity gradients offer the greatest potential energy of the ocean sources considered. (Appendix F.)

• There is a *floating nuclear powerplant (FNP)* concept which is under development. The Nuclear Regulatory Commission (NRC) is expected to decide by June 1978 if Westinghouse Electric Corporation can build eight FNPs. Four have been ordered by the Public Service Electric and Gas Company of New Jersey. Permits for siting two FNPs off the New Jersey coast have been submitted to the NRC, and a decision is expected after September 1978. An agreement has been reached between Westinghouse's Offshore Power Systems and Public Service Electric and Gas Company to delay delivery of the first plant until 1987. (Appendix F.)

• *Aquaculture*, which produces approximately 10 percent of the worldwide supply of fish, can expand to produce three times that amount. In the United States, private aquaculture produces 40 percent of our oysters, 50 percent of our catfish and crawfish, and nearly all of our trout, for a total of 143 million pounds. However, this is only 3 percent of U.S. landings or 1.4 percent of the total U.S. consumption of fisheries products. Expanded aquaculture could involve pen rearing and ocean ranching of salmon, bottom rearing of oysters, raft culture of mussels, and net rearing of edible seaweed, as well as various other methods of developing seafood and fishery products to meet U.S. demands. There is a rapidly expanding aquaculture industry that could impact both commercial and recreational traffic. The required structures could be located in areas being utilized for other maritime purposes. (Appendix F.)

• As the search for *oil* and *gas* moves further *offshore*, greater numbers of drilling rigs, production facilities, and support equipment will be required. Such hardware is extremely varied and includes conventional tankers, four basic types of drilling rigs, tugs, seismic survey ships, submersibles, specialized firefighting/work rigs designed for severe sea states, pipelaying and inspection rigs, etc. Traffic patterns will be modified considerably by the installation of platforms, offshore production facilities, and other associated structures. Air traffic will also increase to expedite movement of personnel and equipment. Vessels will be required to deliver material and to carry products and crude oil to markets ashore. (Appendix F.)

● As *freshwater* becomes increasingly expensive and as alternate sources of supply are sought, offshore desalination systems and iceberg transportation could come into reality. The offshore platforms for desalination plants will require pipeline hookups to shore or tankers to transport the water to potential consumers. Both offshore desalination plants and iceberg transportation will become additional sources of the sea space. As icebergs are moved in or through shipping lanes, increased surveillance of the icebergs will be required. Either calving or loss of the iceberg could pose grave hazards to shipping. Weather patterns may be altered by the placement of large masses of ice near shore. Such masses of ice may pose an additional navigational hazard by causing the formation of fog. (Appendix F.)